Bacteria Total Maximum Daily Load Development for Hat Creek, Piney River, Rucker Run, Mill Creek, Rutledge Creek, Turner Creek, Buffalo River and Tye River in Nelson County and Amherst County, Virginia

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Executive Summary

Background

The Tye River (H09R, H11R, H12R and H13R) watershed is located in Amherst County and Nelson County. The watershed is approximately 267,332 acres in area and is part of the James River Basin. Tye River flows into the James River (USGS Hydrologic Unit Code 02080203) which flows east into Chesapeake Bay.

Segments of Tye River (VAV-H13R_TYE01A00, VAV-H09R_TYE01A00) were listed as impaired on Virginia's 2006 Section 303(d) Report on Impaired Waters due to water quality violations of the *E. coli* standard. Piney River (VAV-H10R_PYN03A04, VAV-H10R_PYN02A00, VAV-H10R_PYN01A00), Hat Creek (VAV-H09R_HAT01A04), Rucker Run (VAV-H13R_RKR01A00), Mill Creek (VAC-H11R_MIN01A08), Turner Creek (VAC-H12R_TNR01A08), Rutledge Creek (VAC-H12R_RTD01A00) and Buffalo River (VAC-H11R_BUF01A00, VAC-H11R_BUF02A00, VAC-H11R_BUF03A00, VAC-H11R_BUF04A08) all tributaries in the Tye River watershed were also listed due to water quality violations of the *E. coli* and/or the fecal coliform standard on Virginia's 305(b)/303(d) Water Quality Assessment Integrated Report reports between 2002 and 2010.

This document describes the Total Maximum Daily Loads (TMDL) for bacteria that were developed for the Hat Creek, Piney River, Rucker Run, Mill Creek, Rutledge Creek, Turner Creek, Buffalo River and Tye River watersheds in order to remedy the bacteria water quality impairments. The TMDLs were developed for the water quality standard for bacteria, which states that the calendar-month geometric mean concentration of *E. coli* shall not exceed 126 cfu/100 mL, and less than 10.5% of the simulated daily *E. coli* concentrations exceeded the instantaneous standard concentration of 235 cfu/mL. A glossary of terms used in the development of this TMDL is listed in Appendix A.

Sources of Bacteria

There are currently six permitted sources that discharge bacteria into the Tye River watershed, one Multiple Separate Storm Sewer System (MS4), one single family domestic point source, three sewage treatment plants, and the Montebello Fish Hatchery. However, the majority of the bacteria load originates from nonpoint sources. The nonpoint sources of bacteria originate from livestock, wildlife, pets, and humans. Significant bacteria loads come from livestock directly depositing feces in the stream. Livestock directly depositing bacteria on the land surface also contribute a significant amount of bacteria to the stream during large storm events. Wildlife contributes bacteria loadings to the stream and all land surfaces, in accordance with the habitat range for each species. Straight pipes discharging household sewage directly into streams, failing septic systems and household pets in residential areas contribute a small amount of bacteria to the streams.

The amounts of bacteria produced in different locations (e.g., streams, pasture, forest) were estimated on a monthly basis to account for seasonal variability in wildlife behavior and livestock production and practices. Livestock management and production factors, such as the fraction of time livestock spend in streams, were considered on a monthly basis. These sources of bacteria can be summarized in two ways. First, Table ES. 1 summarizes the bacteria produced in each location (stream, cropland, pasture, residential, and forest). Land-deposited sources of bacteria undergo die-off and must be transported by runoff from rainfall events into the stream. Direct-deposited sources enter the stream immediately without die-off and without the need for a rainfall event.

The relative contributions given in Table ES. 2 reflect the contributions from each source to the bacteria surviving in-stream at the outlet of Tye River. These surviving bacteria are quantified through modeling (see next section) that takes into account the varied fate and transport processes and represents the fraction of in-stream bacteria attributable to each source for each impaired stream segment. Because the bacteria deposited directly to the stream are subject to less die-off than land deposited sources and do not require a rainfall event to be transferred to the stream, the directly deposited sources compose a higher percentage of surviving bacteria than they do of the overall number of bacteria produced in the watershed.

Table ES. 1. Estimated annual fecal coliform loadings to the stream and the various land use categories for the Tye River watershed.

Source	Fecal coliform loading ($x10^{12}$ cfu/yr)	Percent of total loading
Direct loading to streams		
Livestock in stream	328	0.5%
Wildlife in stream	187	0.3%
Straight pipes	40	0.1%
Point Sources	3.5	<0.1%
Loading to land surfaces		
Cropland	152	0.2%
Pasture	63,219	92%
Residential	3161	4.6%
Forest	1613	2.3%
Total	**68,704**	

Table ES. 2. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in Tye River.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	20	22%
Direct nonpoint source loadings to the stream from wildlife	23	24%
Direct nonpoint source loadings to the stream from livestock	42	46%
Interflow and groundwater contribution	0.7	<1%
Straight-pipe discharges to stream	6	6%
Nonpoint source loadings from impervious land segments	0.1	<1%
Permitted point source loadings	0.6	<1%
All Sources	92	

Modeling

The Hydrological Simulation Program – FORTRAN (HSPF) (Bicknell *et al.*, 2001) was used to simulate the fate and transport of fecal coliform bacteria in the Tye River watershed. HSPF is a continuous model that can represent fate and transport of pollutants on both the land surface and in the stream. As recommended by the Virginia Department of Environmental Quality (VADEQ), water quality modeling was conducted with fecal coliform inputs, and then a translator equation was used to convert the output to *E. coli* for the final TMDLs. To identify localized sources of fecal coliform within the watershed, the Tye River watershed was divided into 50 sub-watersheds based on homogeneity of land use, stream network connectivity, and monitoring station locations.

The hydrology component of HSPF was calibrated using flow data from January 1, 1991 to December 31, 1995; it was validated using data from January 1, 1996 to December 31, 2000. Initial estimates of hydrologic parameters were generated according to the guidance in BASINS Technical Note 6 (USEPA, 2000a). These parameters were refined during calibration. The program Hydrologic Statistics Calculator (HSC) for the Calibration of HSPF was used to aid in calibration, and after the successful calibration the default calibration criteria in HSC were met for both the calibration and validation periods.

The water quality component of the HSPF model was calibrated and validated for Tye River and its tributaries at 11 monitoring stations. The bacteria model was calibrated to data from three stations (2-TYE020.67, 2PNY005.29 and 2 BUF002.10 were the only monitoring station with enough data for calibration) for the periods of January 1, 2007 to June 30, 2010 for Tye River and January 1, 2008 to June 30, 2010 for Piney River. The bacteria model was also validated to data from monitoring stations 2-TYE020.67 (January 1, 2002 to December 31, 2006), 2PNY005.29 (January 1, 2002 to December 31, 2006) and 2 BUF002.10 (January 1, 2005 to December 31, 2007). Additional validation at 8 other monitoring stations was carried out for individual periods between January 1, 2002 to June 30, 2010 (period based on data availability at specific monitoring stations). Inputs to the model included fecal coliform loadings on land and in the stream. A comparison of simulated and observed bacteria loadings in the stream indicated that the model adequately simulated the fate and transport of fecal bacteria.

Existing Conditions

Contributions from various sources in the Tye River watershed were represented in HSPF to establish the existing conditions for a representative 4-year period that included both low and high-flow conditions. This 4-year period used meteorological data from October 2002-September 2006 to represent the appropriate range of conditions. Results from the calibrated HSPF model showed routine high signatures from livestock direct deposit, with some additional contributions from wildlife direct deposit, and overland flow. In Hat Creek, Rucker Run, Mill Creek Turner Creek and Rutledge Creek, contributions from wildlife direct deposit alone (without any other source of bacteria) violated the geometric mean criterion.

Allocation Scenarios

Different source reduction scenarios were evaluated to identify implementable scenarios that meet the calendar-month geometric mean *E. coli* criterion (126 cfu/100 mL) with zero violations. These scenarios were conducted using the same meteorological data used to establish existing conditions. The bacteria loadings used in modeling correspond to anticipated and permitted future conditions for Hat Creek, Piney River, Rucker Run, Mill Creek, Rutledge Creek, Turner Creek, Buffalo River and Tye River. These future conditions differed from existing conditions in that permitted point source dischargers were represented in the model at their maximum permitted limits, with an allocation for potential future permits based on 2% of this permitted amount. The reductions required for each impaired segment to meet the applicable water quality criterion are presented in Table ES. 3. In several segments reductions in wildlife contributions are required; note that in these cases, these are the minimum wildlife reductions needed to attain the criteria under the critical conditions, even if all other bacteria sources were completely eliminated. The critical conditions for most of these watersheds are times of very low flow. One small and three large point sources currently discharge at or below their permit requirements; therefore, the proposed scenarios require load reductions only for nonpoint sources of *E. coli*. Details on the loads to be reduced from each source are given in Table ES. 4 through Table ES. 19.

Table ES. 3. Required *E. coli* loading reductions (%) to meet the *E. coli* standard.

Impaired Segment	Cattle Direct Deposit	Loads from Cropland	Loads from Pasture	Wildlife Direct Deposit	Straight Pipes and Failing Septics	Residential*
Mill Creek	99	5	20	35	100	0
Turner Creek	99	5	30	30	100	0
Rutledge Creek	99	5	10	30	100	0
Buffalo River	90	5	5	0	100	0
Piney River	90	5	25	0	100	0
Hat Creek	99	5	25	30	100	0
Rucker Run	99	5	30	20	100	0
Tye River	70	5	5	0	100	0

* does not include failing septic systems

Table ES. 4. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Mill Creek (Amherst County).

	Existing Conditions		Allocation Scenario	
Land use category	**Existing Conditions Load ($x10^{12}$ cfu/yr)**	**Percent of total land deposited load from nonpoint sources**	**TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)**	**Percent Reduction from Existing Load**
Cropland	3.4	<1	3.2	5
Pasture	1608	97	1287	20
Residential	40	2	12.4	69
Forest	12	<1	12	0
Total	1664		1314	21

Table ES. 5. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Turner Creek (Amherst County).

	Existing Conditions		Allocation Scenario	
Land use category	**Existing Conditions Load ($x10^{12}$ cfu/yr)**	**Percent of total land deposited load from nonpoint sources**	**TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)**	**Percent Reduction from Existing Load**
Cropland	4.6	<1	4.33	5
Pasture	1409	88	986	30
Residential	165	10	57	66
Forest	20	1	20	0
Total	1599		1067	33

Table ES. 6. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Rutledge Creek (Amherst County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	7.4	<1	7.1	5
Pasture	2448	81	2203	10
Residential	514	17	205	60
Forest	59	2	59	0
Total	3028		2475	18

Table ES. 7. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Buffalo River (Amherst County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	128	<1	122	5
Pasture	19188	91	18230	5
Residential	1311	6	524	60
Forest	366	2	366	0
Total	20993		19242	8

Table ES. 8. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Piney River (Amherst County/Nelson County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	22	<1	21	5
Pasture	9811	94	7358	25
Residential	375	4	131	65
Forest	221	2	221	0
Total	10429		7731	26

Table ES. 9. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Hat Creek (Nelson County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	6.8	<1	6.5	5
Pasture	4961	96	3721	25
Residential	115	2	48	58
Forest	78	2	78	0
Total	5161		3854	25

Table ES. 10. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Rucker Run (Nelson County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	21	<1	20	5
Pasture	7269	92	5088	30
Residential	418	5	188	55
Forest	199	3	199	0
Total	7907		5496	31

Table ES. 11. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Tye River watershed (Nelson County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	152	<1	144	5
Pasture	63219	93	60058	5
Residential	3161	5	1264	60
Forest	1613	2	1613	0
Total	68145		63079	7

Table ES. 12. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Mill Creek (Amherst County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	7.7	64	0.08	99
Straight Pipes	1.6	13	0	100
Wildlife in Streams	2.8	23	1.81	35
Total	12.1		1.89	84

Table ES. 13. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Turner Creek (Amherst County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	9	62	0.09	99
Straight Pipes	1.6	11	0	100
Wildlife in Streams	4	27	2.78	30
Total	14.6		2.87	80

Table ES. 14. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Rutledge Creek (Amherst County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	23	61	0.2	99
Straight Pipes	4	11	0	100
Wildlife in Streams	11	28	7.6	30
Total	38		7.8	80

Table ES. 15. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Buffalo River (Amherst County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	106	58	11	90
Straight Pipes	11	6	0	100
Wildlife in Streams	65	35	65	0
Total	182		76	59

Table ES. 16. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Piney River (Amherst County/Nelson County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	55	65	5.5	90
Straight Pipes	10	11	0	100
Wildlife in Streams	20	23	20	0
Total	85		25.5	70

Table ES. 17. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Hat Creek (Nelson County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	26	58	0.26	99
Straight Pipes	7	15	0	100
Wildlife in Streams	12	27	8.4	30
Total	45		8.66	81

Table ES. 18. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Rucker Run (Nelson County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	46	66	0.46	99
Straight Pipes	3	4	0	100
Wildlife in Streams	21	30	15	30
Total	70		15.46	78

Table ES. 19. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Tye River (Nelson County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	328	59	98	70
Straight Pipes	40	7	0	100
Wildlife in Streams	187	34	187	0
Total	555		285	49

Equation ES.1 was used to calculate the TMDL allocations shown in Table ES. 20.

$$TMDL = WLA_{total} + LA + MOS \qquad [ES.1]$$

where:

WLA_{total} = wasteload allocation (point source contributions, including future growth);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

Table ES. 20. Annual and daily *E. coli* loadings for the TMDLs.

Impairment	Units	WLA_{total}	LA	MOS*	TMDL
Hat Creek	cfu/yr	6.02×10^{11}	2.86×10^{13}	--	2.92×10^{13}
	cfu/day	1.65×10^{9}	7.29×10^{11}	-	7.31×10^{11}
Piney River	cfu/yr	2.44×10^{12}	1.20×10^{14}	--	1.22×10^{14}
	cfu/day	6.88×10^{9}	2.65×10^{12}	-	2.66×10^{12}
Rucker Run	cfu/yr	1.32×10^{12}	6.47×10^{13}	--	6.60×10^{13}
	cfu/day	3.62×10^{9}	1.88×10^{12}	-	1.89×10^{12}
Mill Creek	cfu/yr	2.08×10^{11}	9.98×10^{12}	--	1.02×10^{13}
	cfu/day	5.70×10^{8}	1.69×10^{11}	-	1.70×10^{11}
Rutledge Creek	cfu/yr	1.15×10^{12}	2.03×10^{13}	--	2.15×10^{13}
	cfu/day	3.15×10^{9}	6.65×10^{11}	-	6.68×10^{11}
Turner Creek	cfu/yr	1.57×10^{11}	7.71×10^{12}	--	7.87×10^{12}
	cfu/day	4.31×10^{8}	2.63×10^{11}	-	2.63×10^{11}
Buffalo River	cfu/yr	2.54×10^{12}	1.25×10^{14}	--	1.27×10^{14}
	cfu/day	6.96×10^{9}	3.85×10^{12}	-	3.86×10^{12}
Tye River	cfu/yr	1.33×10^{13}	5.75×10^{14}	--	5.88×10^{14}
	cfu/day	3.64×10^{10}	1.57×10^{13}	-	1.57×10^{13}

*Implicit MOS

The TMDL was determined as the average annual *E. coli* load at the watershed outlets for the chosen allocation scenarios. The WLAs for Rutledge Creek and Tye River were determined as approximately 2% of the total TMDL load to allow for future growth in permitted facilities (the existing WLA in each watershed represented ≤ 10% of the TMDL). To account for future growth to the impaired segments with no permitted point sources and where the existing WLA in the watershed represents ≤ 10% of the TMDL (i.e., Hat Creek, Piney River, Rucker Run, Mill Creek, Turner Creek and Buffalo River), 2% of the TMDL was added to the waste load allocation. The margin of safety for all of these TMDLs was implicit and achieved through conservative assumptions of bacteria loading and management practices as detailed throughout this report.

Transitional Scenario

The implementation of a transitional scenario, or Stage 1 implementation, will allow for an evaluation of the effectiveness of management practices and accuracy of model assumptions through data collection. Stage 1 implementation was developed with a target of a 10.5% violation rate of the instantaneous *E. coli* water quality criterion (235 cfu/100 mL) and no reductions in wildlife sources. The Stage 1 scenarios are given in Table ES. 21 for each impaired segment.

Table ES. 21. Allocation scenarios for Stage 1 TMDL implementation for the Tye River watersheds.

Impaired Segment	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %							% Violation of *E. coli* Single Sample Standard
	Livestock Direct Deposit	Loads from Cropland	Loads from Pasture	Straight Pipes & Failing Septic Systems	Non-Human Loads from Residential Areas*	Wildlife Direct Deposit	Loads from Forested Areas	
Hat Creek	75	5	25	100	0	0	0	10
Piney River	40	5	25	100	0	0	0	10
Rucker Run	65	5	25	100	0	0	0	10
Mill Creek	80	5	20	100	0	0	0	10
Rutledge Creek	60	5	30	100	0	0	0	9
Turner Creek	65	5	30	100	0	0	0	10
Buffalo River	10	5	5	100	0	0	0	9
Tye River	10	5	5	100	0	0	0	6

* does not include failing septic systems

Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in attainment of water quality standards. This report represents the culmination of that effort for the bacteria impairments on Hat Creek, Piney River, Rucker Run, Mill Creek, Rutledge Creek, Turner Creek, Buffalo River and Tye River. The second step is to develop a TMDL implementation plan. The final step is to initiate recommendations outlined in the TMDL implementation plans and to monitor stream water quality to determine if water quality standards are being attained.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR, and other cooperating agencies.

Public Participation

Public participation was solicited at every stage of TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. In July 2012, members of the Center for Watershed Studies at Virginia Tech traveled to Amherst County and Nelson County for a day trip around the impaired watersheds to become acquainted with them. Throughout the process, personnel from Virginia Tech contacted stakeholders and local agency personnel via telephone, email, and in person to acquire their input.

In Nelson County, numerous technical advisory committee meetings were held to inform stakeholders of the TMDL process and solicit feedback. These were held on June 12, 2012 (Nelson County Government Center, Lovingston, Virginia), September 10, 2012 (Massies Mill Ruritan Club, Roseland, Virginia), November 14, 2012 (Massies Mill Ruritan Club, Roseland, Virginia), March 26, 2013 (Massies Mill Ruritan Club, Roseland, Virginia) and April 3, 2013 (Massies Mill Ruritan Club, Roseland, Virginia). These meetings provided a forum for a group of interested stakeholders and agency personnel to provide detailed feedback on the estimates and methods used in these TMDLs. The first Public Meeting in Nelson County was held on July 9, 2012 at the Massies Mill Ruritan Club in Roseland, Virginia. The purpose of that meeting was to introduce the public to the TMDL process and to discuss the impairments identified on stream segments in these watersheds. The final Public Meeting in Nelson County was held on May 22, 2013 at the Massies Mill Ruritan Club in Roseland, Virginia to present the draft bacteria TMDL report for Hat Creek, Rucker Run, Piney River, and Tye River.

In Amherst County, technical advisory committee meetings were held on June 14, 2012, March 26, 2013, and April 17, 2013 at the Central Virginia Community College, Amherst, Virginia. The first Public Meeting was held on June 25, 2012 at the

Central Virginia Community College, Amherst, Virginia. A final Public Meeting to present the draft bacteria TMDL report for Mill Creek, Turner Creek, Buffalo River and Rutledge Creek, and the draft sediment TMDL report for Long Branch and Buffalo River was held on April 25, 2013 at the Central Virginia Community College, Amherst, Virginia.

The public comment period on the Bacteria TMDL report for the Tye River watershed ended on June 24, 2013. Comments were received and addressed in the report.

Chapter 1: Introduction

1.1. Background

1.1.1. TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify water bodies that violate state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL reflects the total pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

1.1.2. Impairment Listing

Segments of Tye River (VAV-H13R_TYE01A00, VAV-H09R_TYE01A00) were listed as impaired on Virginia's 2006 Section 303(d) Report on Impaired Waters due to water quality violations of the *E. coli* standard. Piney River (VAV-H10R_PYN03A04, VAV-H10R_PYN02A00, VAV-H10R_PYN01A00), Hat Creek (VAV-H09R_HAT01A04), Rucker Run (VAV-H13R_RKR01A00), Mill Creek (VAC-H11R_MIN01A08), Turner Creek (VAC-H12R_TNR01A08), Rutledge Creek (VAC-H12R_RTD01A00) and Buffalo River (VAC-H11R_BUF01A00, VAC-H11R_BUF02A00, VAC-H11R_BUF03A00, VAC-H11R_BUF04A08), all tributaries in the Tye River watershed, were also listed due to water quality violations of the *E. coli* and/or the fecal coliform standard on Virginia's 305(b)/303(d) Water Quality Assessment Integrated Report reports between 2002 and 2010. The Virginia Department of Environmental Quality (VADEQ) has described the impaired segments as presented in Figure 1.1 and Table 1.1.

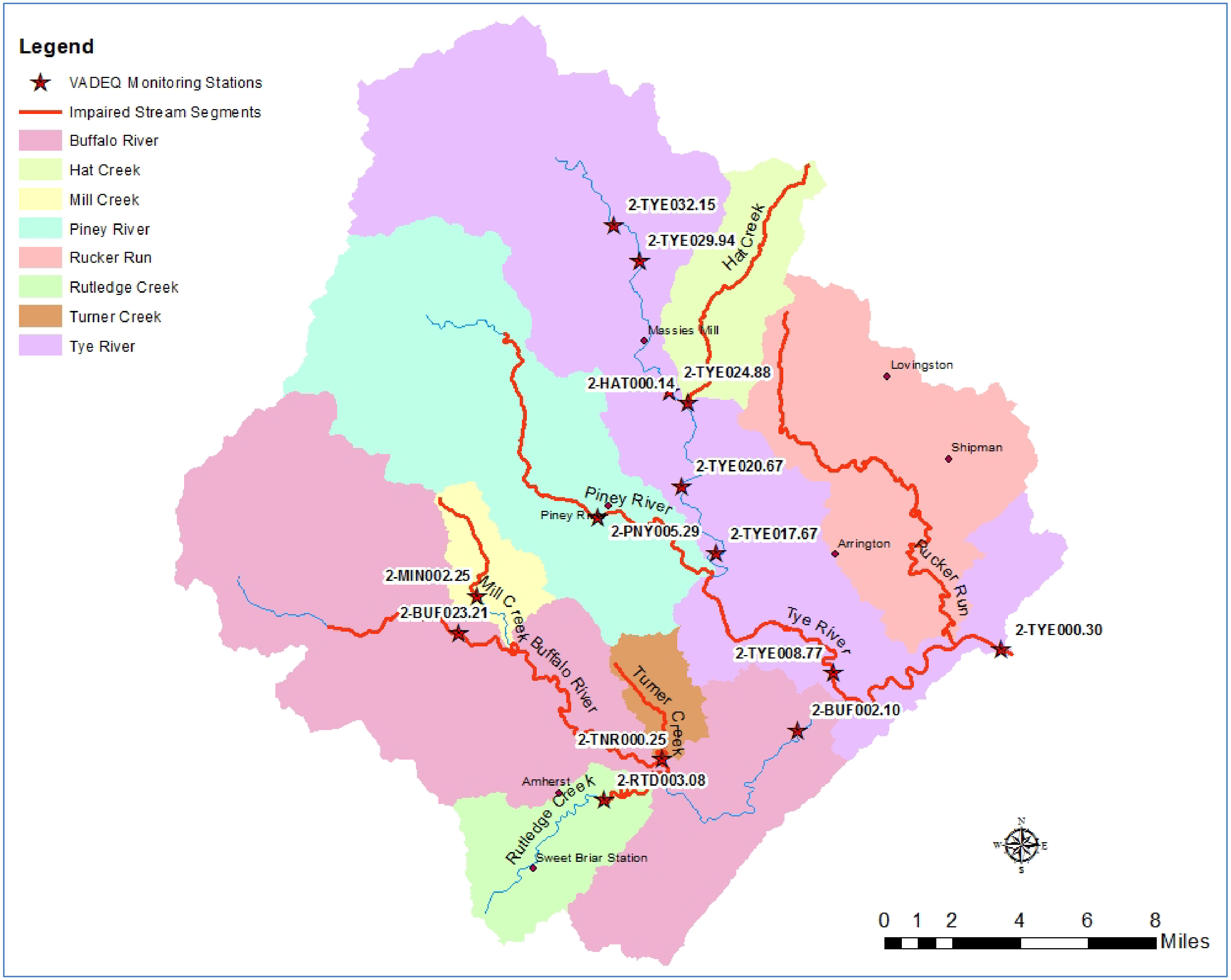

Figure 1.1. Impaired segments in the Tye River watershed.

Table 1.1. Impaired Segments Addressed in this TMDL report.

Impaired Segment	Size	Initial Listing Year	Description
Hat Creek (VAV-H09R_HAT01A04)	9.58 miles	2004	extending from the headwaters downstream to its confluence with the Tye River
Tye River (VAV-H13R_TYE01A00, VAV-H09R_TYE01A00)	15.94 miles	2006	extending from its confluence with Piney River downstream to its confluence with the James River
Buffalo River (VAC-H11R_BUF01A00, VAC-H11R_BUF02A00, VAC-H11R_BUF03A00, VAC-H11R_BUF04A08)	15.38 miles	2010	extending from the confluence of Franklin Creek to the confluence with Rutledge Creek
Mill Creek (VAC-H11R_MIN01A08)	3.92 miles	2008	extending from its headwaters to the backwaters of Mill Creek Reservoir
Rutledge Creek (VAV-H13R_RKR01A00)	3.16 miles	2002	extending from the Town of Amherst outfall downstream to its mouth on the Buffalo River
Turner Creek (VAC-H12R_TNR01A08)	4.36 miles	2008	extending from its headwaters to the confluence with Buffalo River
Rucker Run (VAV-H13R_RKR01A00)	18.26 miles	2004	extending from the headwaters downstream to its confluence with the Tye River
Piney River (VAV-H10R_PYN03A04, VAV-H10R_PYN02A00, VAV-H10R_PYN01A00)	13.30 miles	2008	extending from a point 13.3 miles upstream of the Tye River downstream to its confluence with the Tye River

1.1.3. Watershed Location and Description

The Tye River watershed is located in Amherst County and Nelson County. (Figure 1.2). The watershed is approximately 267,332 acres in area and is part of the James River Basin. The predominant land use in the Tye River watershed is forest (75%), with additional significant areas in pasture and hay land (15%); less significant land uses are residential (6%) and cropland (4%). Tye River flows into the James River which flows east into Chesapeake Bay.

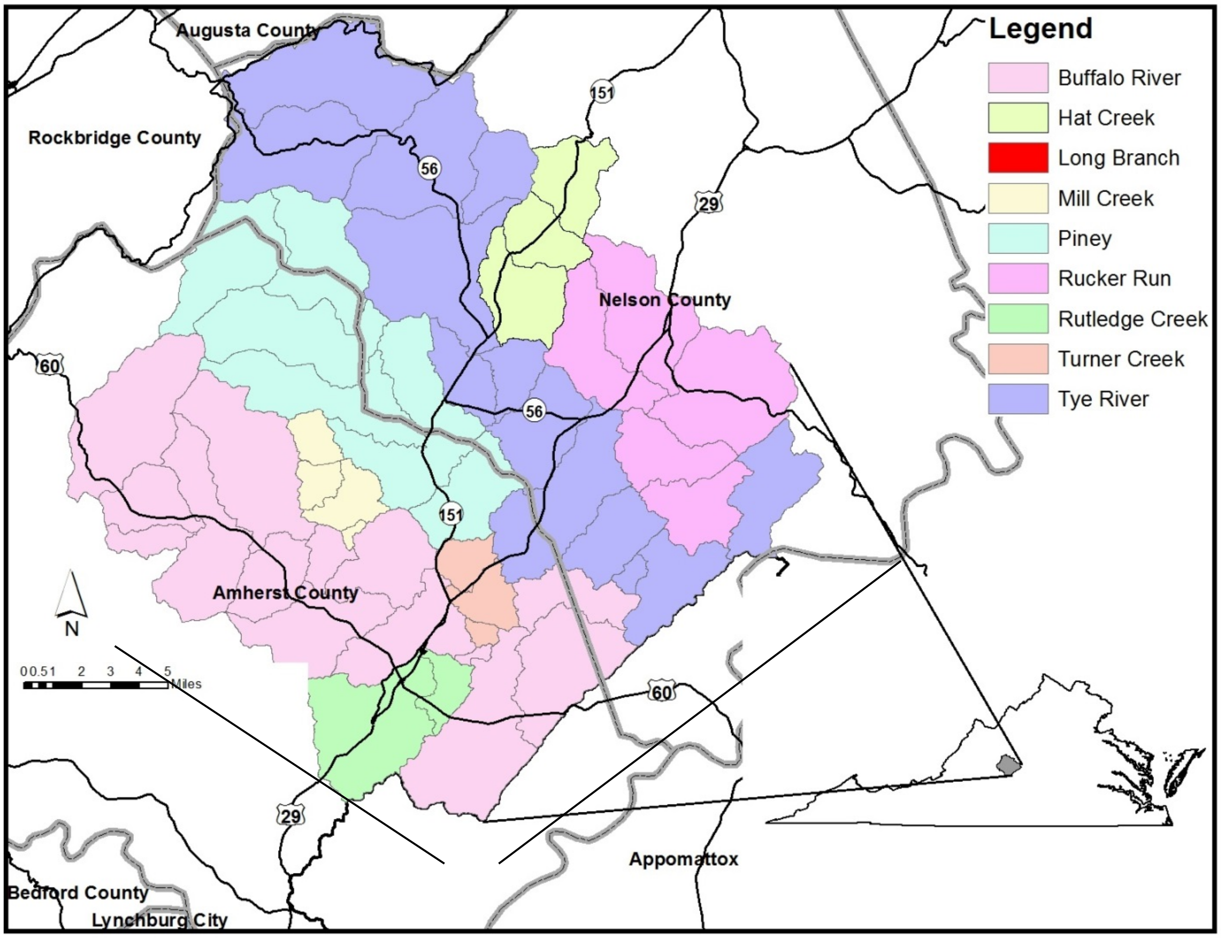

Figure 1.2. Tye River watershed location.

1.1.4. Pollutants of Concern

Pollution from both point and nonpoint sources can lead to fecal coliform bacteria contamination of water bodies. Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals; consequently, fecal waste of warm-blooded animals contains fecal coliform. Even though most fecal coliform are not pathogenic, their presence in water indicates contamination by fecal material. Because fecal material may contain pathogenic organisms, water bodies with fecal coliform bacteria are potential sources of pathogenic organisms. For contact recreational activities such as boating and swimming, health risks increase with increasing fecal coliform counts. If the fecal coliform concentration in a water body exceeds state water quality standards, the water body is listed for violation of the state bacteria standard for contact recreational uses. As will be discussed in Section 1.2.2, Virginia has adopted an *Escherichia coli* (*E. coli*) water quality standard. The concentration of *E. coli* (a subset of the fecal coliform group) in water is considered to be a better indicator of pathogenic exposure than the concentration of the entire fecal coliform group in the water body.

1.2. Designated Uses and Applicable Water Quality Standards

1.2.1. Designation of Uses (9 VAC 25-260-10)

"A. All State waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish." SWCB, 2011.

Hat Creek, Piney River, Rucker Run, Mill Creek, Rutledge Creek, Turner Creek, Buffalo River and Tye River do not support the recreational (primary contact) designated use due to violations of the bacteria standard.

1.2.2. Bacteria Standard (9 VAC 25-260-170)

EPA has recommended that all states adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters, because there is a strong correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness. *E. coli* and enterococci are bacteria that can be found in the intestinal tract of warm-blooded animals and are subsets of the fecal coliform and fecal streptococcus groups, respectively. In line with this recommendation, Virginia adopted and published revised bacteria criteria on June 17, 2002. The revised criteria became effective on January 15, 2003. As of that date, the *E. coli* standard described below applies to all freshwater streams in Virginia.

For a non-shellfish water body to be in compliance with Virginia's revised bacteria standards the following criterion shall apply to protect primary contact recreational uses (SWCB, 2011):

***Escherichia coli* Standard:**

E. coli bacteria concentrations for freshwater shall not exceed a monthly geometric mean of 126 colony forming units (cfu) per 100 mL.

During any assessment period, if more than 10.5% of a station's samples exceed 235 *E. coli* cfu/100mL, the stream segment associated with that station is classified as impaired and a TMDL must be developed and implemented to bring the station into compliance with the water quality standard. There are 32 ambient monitoring stations in the impaired Tye River watershed: eleven on Tye River, eight on Buffalo River, two on Rucker Run, four on Piney River, three on Mill Creek, two on Rutledge Creek, one each on Hat Creek and Turner Creek. All the stream segment detailed in section 1.1.2 have a violation rate greater than 10.5% of the instantaneous target concentration of 235 cfu/100ml, leading to the impaired classification.

The bacteria TMDL for the impaired segments will be developed to meet the *E. coli* standard of a monthly geometric mean not exceeding 126 *E. coli* cfu/100mL. The modeling will be conducted with fecal coliform inputs, and then a translator equation will be used to convert the output to *E. coli* concentrations.

Chapter 2: Watershed Characterization

2.1. Selection of Sub-watersheds

To account for the spatial distribution of fecal coliform sources, the Tye River watershed was subdivided into 50 sub-watersheds as shown in Figure 2.1. The impaired streams and their corresponding sub-watersheds are given in Table 2.1. The stream network used to help define the sub-watersheds was obtained from the National Hydrography Dataset. Sub-watersheds were delineated based on a number of factors: continuity of the stream network, similarity of land use distribution, and monitoring station locations. It is preferable to have a sub-watershed outlet at or near monitoring station locations in order to calibrate the model chosen for this study (to be discussed in Chapter 4); the monitoring stations used in modeling are also shown in Figure 2.1

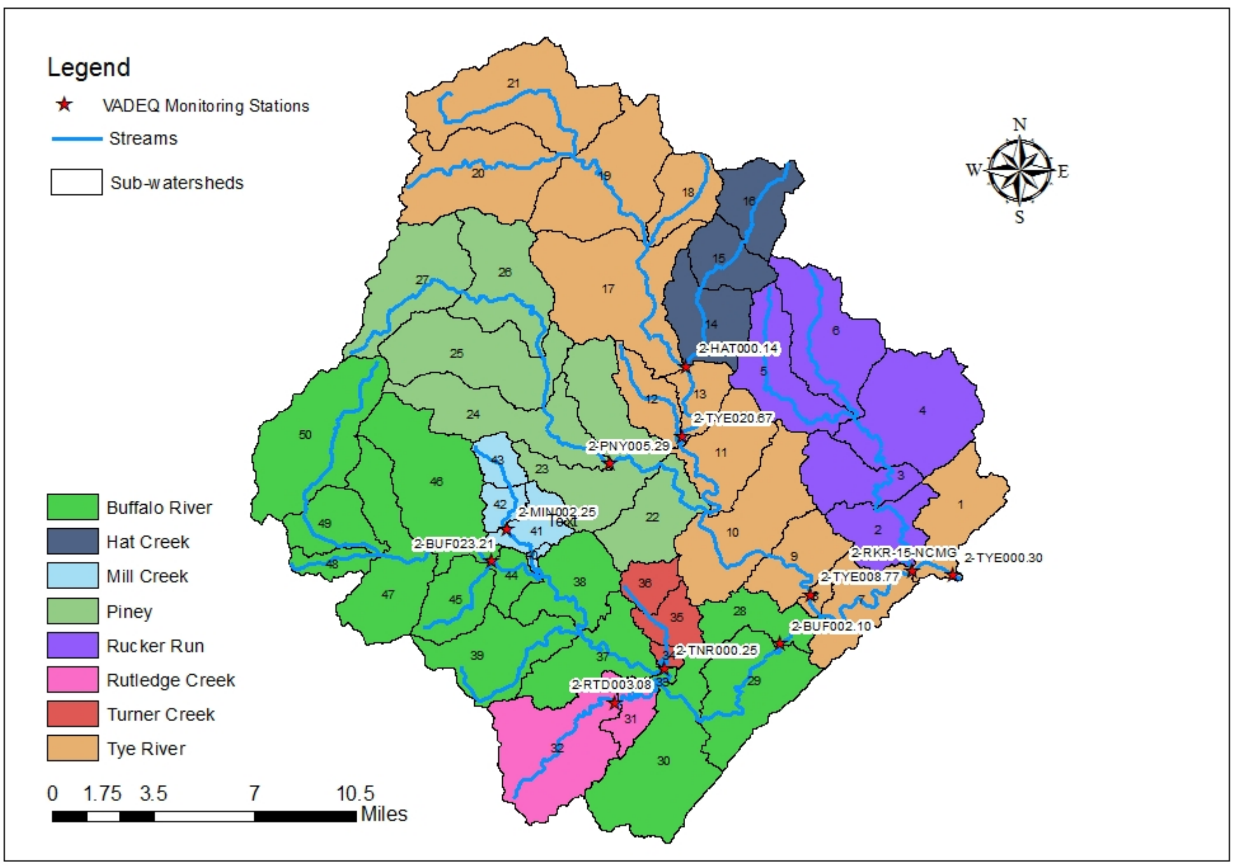

Figure 2.1. Sub-watersheds for the Tye River watershed.

Table 2.1. Impaired streams and corresponding sub-watersheds.

Stream Name	Corresponding Sub-watersheds
Tye River	1, 7 - 13, 17 - 21,
Rucker Run	2 – 6
Hat Creek	14 – 16
Piney River	22 – 27
Buffalo River	28 – 30, 37 – 41, 44 - 50
Turner Creek	34 – 36
Rutledge Creek	31 – 32
Mill Creek	42 - 43

2.2. Ecoregion, Soil and Climate

The majority of the Tye River watershed lies in the, Northern Inner Piedmont Level IV Ecoregion. The northern and eastern part of the Tye River watershed, having the highest elevations, is located Northern Igneous Ridges IV Ecoregion. A portion of the southeastern corner of the watershed has areas that lie in the Piedmont Uplands Level IV Ecoregion. Scattered areas in the western portion of the watershed are located in the Southern Shale Valleys Level IV Ecoregion. The far northern part of the watershed lies in the Metasedimentary Ridges Level IV Ecoregion.

The finer resolution Soil Survey Geographic (SSURGO) soils were used for modeling purposes. The most dominant soil group was Clifford loam. Other dominant soil groups Stott Knob-Rhodhiss complex and Edneytown-Peaks, Peaks-Rock outcrop complex and Elioak loam. The five most ubiquitous soil groups represented in the study area are presented here to simplify the overall watershed soil characterization discussion. For example, soils in hydrologic group “A” pass a larger proportion of rainfall through to ground water than soils in hydrologic group “B.” Conversely, soils in hydrologic group “D” inhibit infiltration such that a large proportion of rainfall contributes to surface runoff and therefore a more direct path to stream channels. These processes have consequences for bacteria residing on the land surface in terms of the potential bacteria loads transported to streams during storm events.

The climate of the watershed was characterized based on the meteorological observations acquired from the National Climatic Data Center (NCDC) for “nearby” weather stations (NCDC, 2007). Meteorological data were obtained primarily from the National Weather Service COOP station at the Montebello Fish Hatchery (COOP ID

445690). The Montebello Fish Hatchery station is located within sub-watershed 20. Data from the following stations were used to address missing data in the Montebello Fish Hatchery record: Bremo Bluff, Tye River 1 SE, Charlottesville 2 W, and Lynchburg Regional Airport. The long-term record summary (7/5/1937-6/30/2000) at the nearby Montebello station (COOP ID 445685, 2.4 miles north) shows an average annual precipitation of 50.28 inches, with 53% of the precipitation occurring during the cropping season (May-October). Mean annual snowfall at the Montebello station is 23.7 inches. Average annual daily temperature is 51.7°F, with the highest average daily temperature of 71.0°F occurring in July, and the lowest average daily temperature of 34.9°F occurring in December (SERCC, 2011).

2.3. Land Use

The National Agricultural Statistics Service (NASS) 2009 cropland data layer (CDL) land use map for Virginia was used to obtain the land use estimates. This layer uses satellite imagery from sources such as the Indian Remote Sensing RESOURCESAT-1, Landsat 5 TM, and Landsat 7 ETM+, supplemented by the USGS National Elevation Dataset, USGS National Land Cover Dataset 2001, and NASA Moderate Resolution Imaging Spetroradiometer data. The dataset was verified using the Farm Service Agency's Common Land Unit program and NLCD 2001 data (USDA-NASS, 2009). The land cover categories in the Tye River watershed were grouped into five major categories based on similarities in hydrologic features and waste application/production practices (Table 2.2). The land use categories were assigned pervious and impervious percentages for use in the watershed model. Cropland acreages were initially considered to be too low based on stake holder communications and subsequently increased to reflect recommendations. Land uses for the Tye River watershed are presented graphically in Figure 2.2 and tabulated in Table 2.3.

Table 2.2. NASS and land use aggregation.

TMDL Land Use Categories	Pervious/Impervious (Percentage)	NASS Land Use Categories (Class No.)
Cropland	Pervious (100%)	Corn (1) Soybeans (5) Barley (21) Winter Wheat (24) W. Wht./Soy. Dbl. Crop (26) Rye (27) Oats (28) Millet (29) Alfalfa (36) Fallow/Idle Cropland (61) Dbl. Crop WinWht/Corn (225) Pumpkin (229) Dbl. Crop Barley/Corn (237) Dbl. Crop Soybeans/Oats (240)
Hayland	Pervious (100%)	Other Hays (37)
Pasture	Pervious (100%)	Grass/Pasture (62) NLCD - Grassland Herbaceous (171)
Residential	Pervious (90%); Impervious (10%) Pervious (65%); Impervious (35%) Pervious (35%); Impervious (65%) Pervious (10%); Impervious (90%) Pervious (100%)	NLCD - Developed/Open Space (121) NLCD - Developed/Low Intensity (122) NLCD - Developed/Medium Intensity (123) NLCD - Developed/High Intensity (124) NLCD – Barren (131)
Forest	Pervious (100%)	NLCD - Deciduous Forest (141) NLCD - Evergreen Forest (142) NLCD - Mixed Forest (143) NLCD – Shrubland (152) NLCD - Woody Wetlands (190) NLCD - Herbaceous Wetlands (195)
Water	Pervious (100%)	NLCD - Open Water (111)

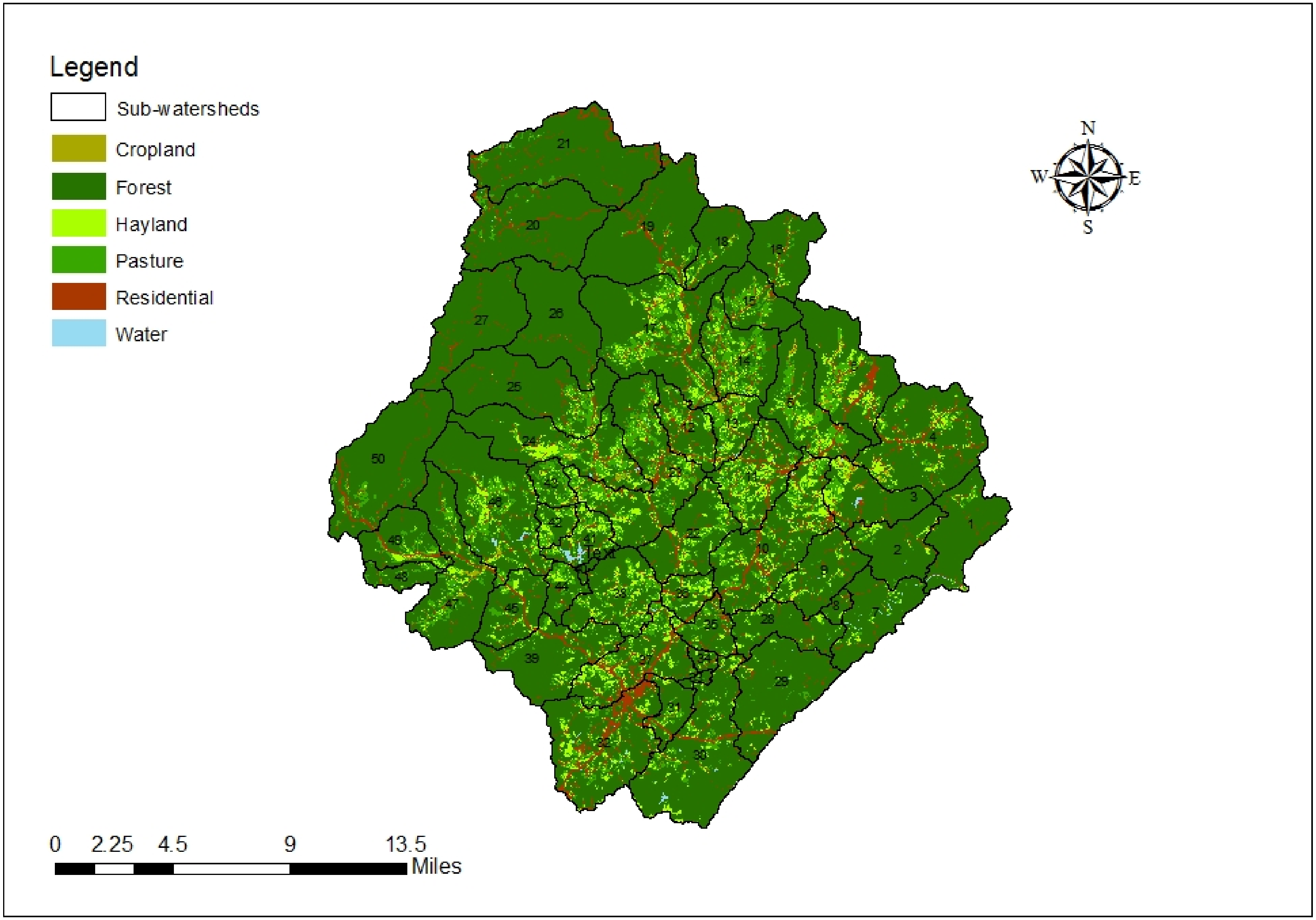

Figure 2.2. Land use in the Tye River watershed.

Table 2.3. Land use areas in the Tye River watershed (acres).

Sub-watershed	Cropland	Forest	Pasture	Residential	Water	Total
1	80	4900	161	166	25	5332
2	198	3826	162	121	1	4308
3	568	3151	363	245	40	4367
4	702	7795	636	671	2	9806
5	566	4010	1142	330	2	6050
6	655	5407	941	583	5	7591
7	141	4171	189	113	49	4664
8	25	529	20	31	0	605
9	292	3415	260	229	5	4201
10	1202	5492	1432	917	12	9055
11	898	2871	990	547	12	5318
12	271	1936	550	321	5	3083
13	540	1067	686	195	24	2512
14	531	2609	1530	355	6	5031
15	179	2284	653	158	1	3275
16	78	3721	198	137	0	4134
17	1051	7956	1977	575	12	11571
18	121	2988	193	105	0	3407
19	105	8779	323	405	0	9612
20	7	8303	291	444	6	9051
21	18	9946	261	698	2	10925
22	451	3700	619	303	0	5073
23	1273	5612	2162	670	18	9735
24	895	5177	1127	362	27	7588
25	231	7407	655	324	2	8619
26	11	6920	34	112	0	7077
27	0	6953	4	216	0	7173
28	206	3129	217	162	1	3715
29	127	6631	262	271	4	7295
30	562	8262	832	439	41	10136
31	150	1308	259	234	2	1953
32	823	6063	1058	1434	36	9414
33	17	248	30	11	0	306
34	60	344	51	55	0	510

Sub-watershed	Cropland	Forest	Pasture	Residential	Water	Total
35	207	1353	341	271	0	2172
36	343	904	365	180	4	1796
37	866	2887	1082	854	12	5701
38	676	3381	930	228	2	5217
39	350	5248	471	308	0	6377
40	3	236	7	8	1	255
41	414	1233	477	137	157	2418
42	256	661	334	62	1	1314
43	192	841	490	56	0	1579
44	167	1041	297	46	0	1551
45	240	2798	434	201	0	3673
46	719	7249	1504	361	60	9893
47	428	6019	981	324	3	7755
48	39	1206	245	36	0	1526
49	221	2650	442	201	0	3514
50	36	9243	397	421	0	10097
Total	18191	203860	29065	15,633	580	267,332

2.4. Water Quality Data

11 VADEQ water quality monitoring stations within the impaired Tye River watersheds were used for model development. The locations of these stations were shown previously (Figure 2.1). A summary of the bacteria data, including violation rates of the appropriate single-sample standards, is presented in Table 2.4.

Table 2.4. VADEQ monitoring stations within the Tye River watershed used in model development.

Station ID	Stream Name	Indicator Organism Measured	Number of Samples	Violation Rate	Period of Record
2-TYE000.30	Tye River	*E. coli*	16	13%	2005 - 2012
2-RKR000.20	Rucker Run	*E. coli*	13	23%	2010 - 2012
2-TYE008.77	Tye River	*E. coli*	24	21%	2004 - 2012
2-TYE020.67	Tye River	*E. coli*	57	15%	2002 - 2012
2-HAT000.14	Hat Creek	*E. coli*	25	40%	2007 – 2012
2-PNY005.29	Piney river	*E. coli*	91	31%	2002 - 2012
2-BUF002.10	Buffalo River	*E. coli*	54	15%	2005 - 2012
2-TNR000.25	Turner Creek	*E. coli*	29	30%	2005 - 2012
2-RTD003.08	Rutledge Creek	*E. coli*	24	33%	2010 - 2011
2-MIN002.25	Mill Creek	*E. coli*	20	47%	2006 - 2010
2-BUF023.21	Buffalo River	*E. coli*	27	19%	2005 - 2010

Seasonality of fecal coliform concentrations in the streams was evaluated by plotting the mean monthly fecal coliform concentrations observed at station 2-TYE020.67, the station with the longest period of record (Figure 2.3). Mean monthly fecal coliform concentration was determined as the mean of all values in any given month for the period of record; there were between 4 and 7 samples available for every month (2002-2010). The observed bacteria record shows little seasonality, except perhaps to show that bacteria concentrations observed in April, May and October are higher than the other months.

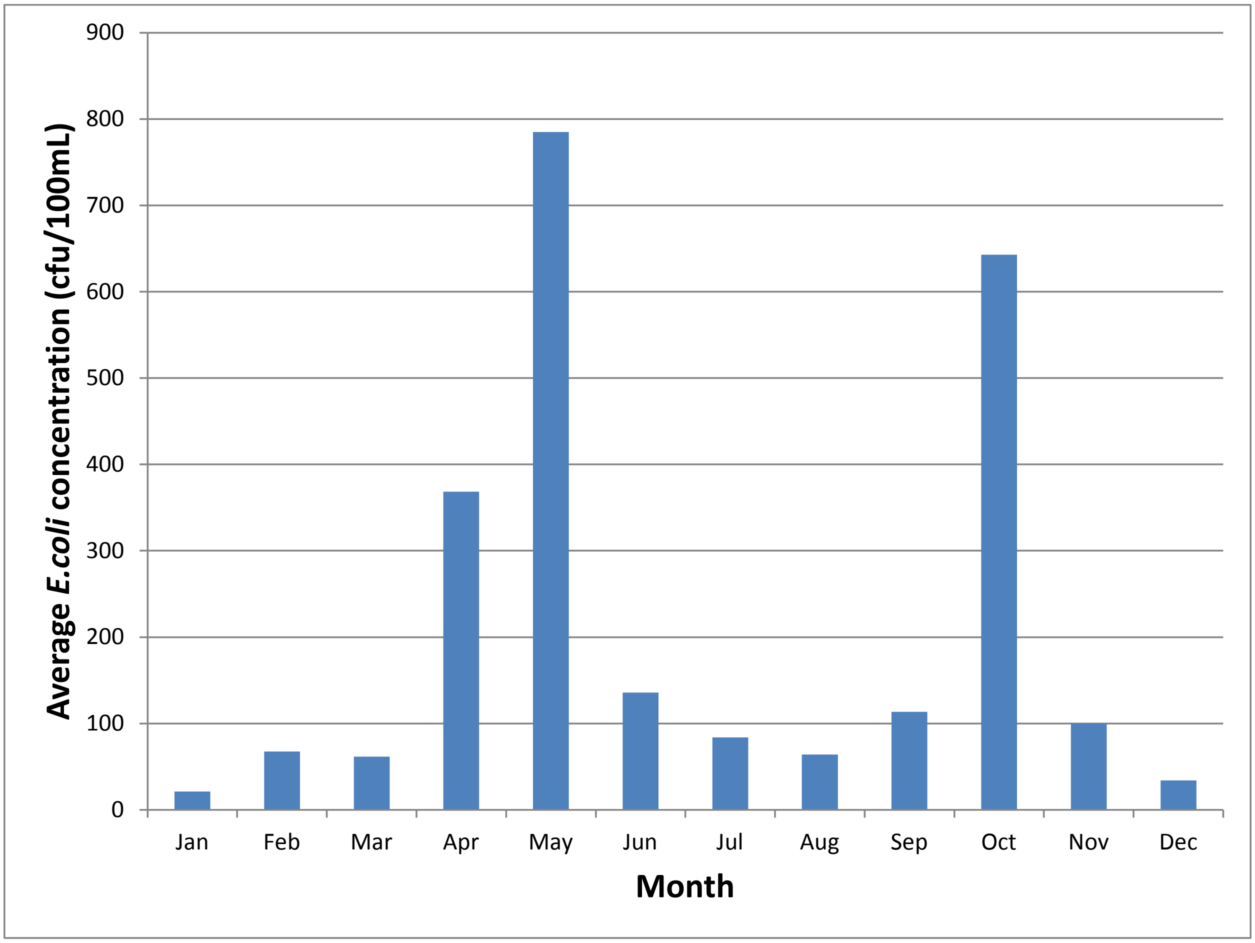

Figure 2.3. Average fecal coliform concentrations by month for station 2-TYE 020.67.

The relationships between flow conditions and *E. coli* concentrations are shown in Figures 2.4 through 2.7 for each of the monitoring stations used in model development. The stream flow conditions were derived from the nearest USGS gaging station. Station ID 2027000 on the Tye River near Lovingston was used for all comparisons except the Piney River. USGS station ID 2027500 on the Piney River at Piney River was used to compare the *E. coli* concentrations from DEQ monitoring station 2-PNY005.29 to flow conditions. Daily stream flow data from 1993 to 2012 were used to rank flow conditions. Exceedances of the instantaneous *E. coli* water quality standard (235 cfu/100mL) during low flow conditions indicate that fecal bacteria loads at quantities exceeding the water quality standard are directly deposited into the stream, while exceedances during high flow conditions most likely indicate bacteria loads are entering the stream from runoff.

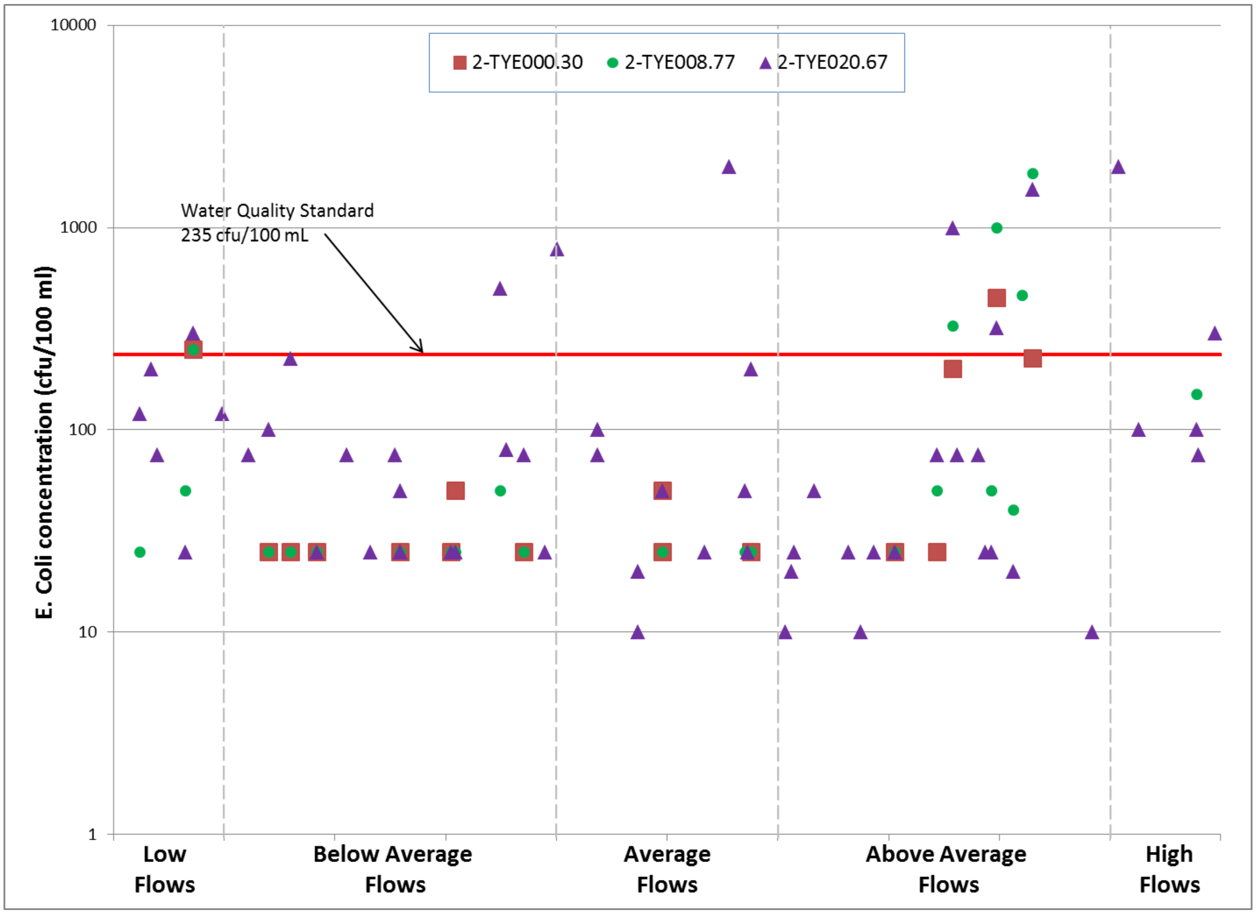

Figure 2.4. Flow conditions and *E. coli* concentrations for Tye River.

In Tye River, the monitored data at station 2-TYE020.67 reveal that exceedances of the water quality standard occur across all flow conditions, indicating that *E. coli* concentrations exceeding the water quality standard are both runoff based and directly deposited into the stream. The monitored data at station 2-TYE008.77 on Tye River, approximately 12 miles downstream from the 2-TYE020.67 station, show that exceedances of the water quality standard occur mainly during above average flow conditions, suggesting that fecal bacteria in runoff from land areas is the most likely cause of violations. Only two samples collected at station 2-TYE000.30, near the outlet of Tye River, show violations of the water quality standard, one during low flows and one during above average flows, suggesting that bacteria concentrations exceeding the water quality standard are both runoff based and directly deposited into the stream.

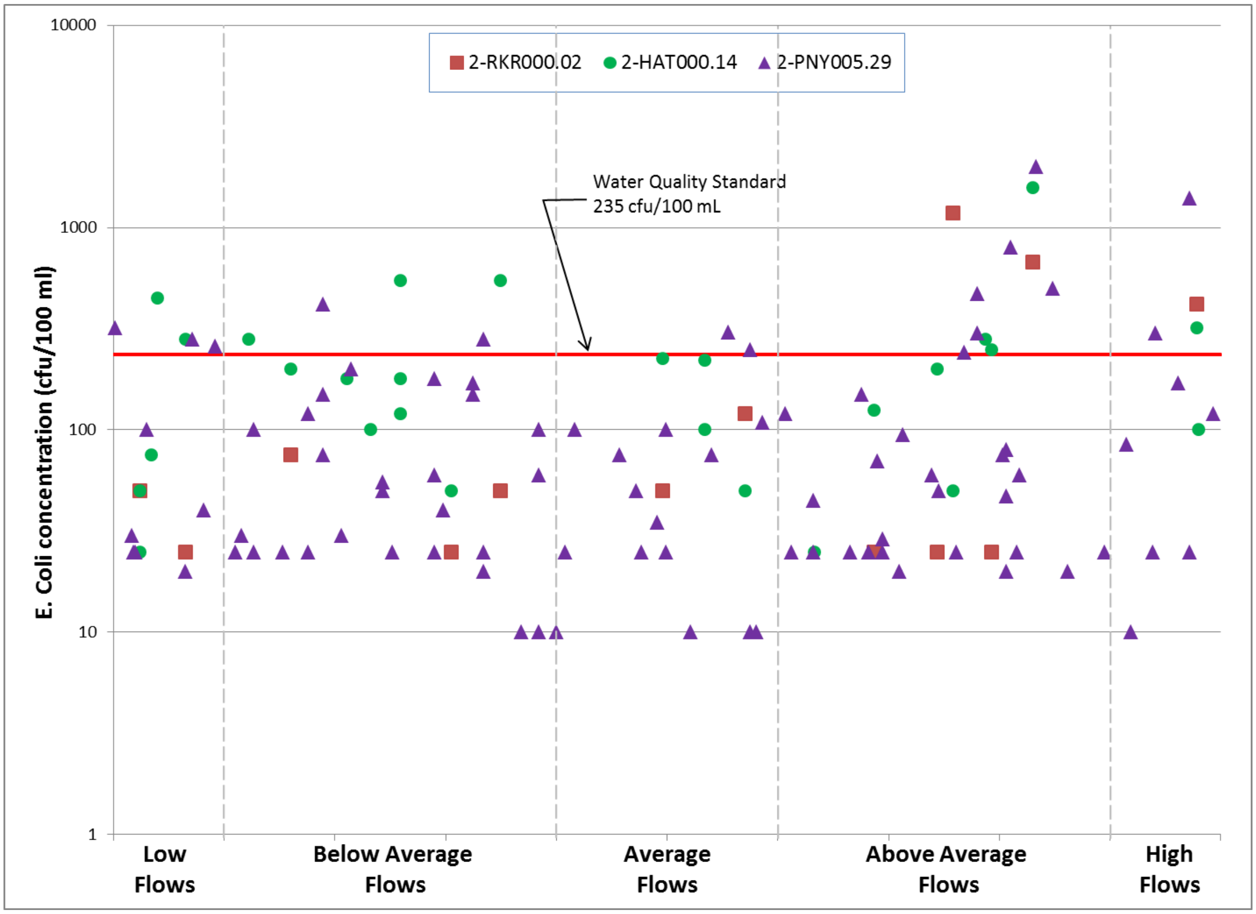

Figure 2.5. Flow conditions and *E. coli* concentrations for Rucker Run, Hat Creek and Piney River.

In Rucker Run, the monitored data at station 2-RKR000.02 show all of the exceedances of the water quality standard occur during above average and high flow conditions, suggesting that fecal bacteria in runoff from land areas is the most likely cause of violations. The monitored data on Hat Creek at station 2-HAT000.14 and on Piney River at station 2-PNY005.29 show exceedances of the water quality standard across all flow conditions, indicating that bacteria concentrations exceeding the water quality standard are both runoff based and directly deposited into the stream.

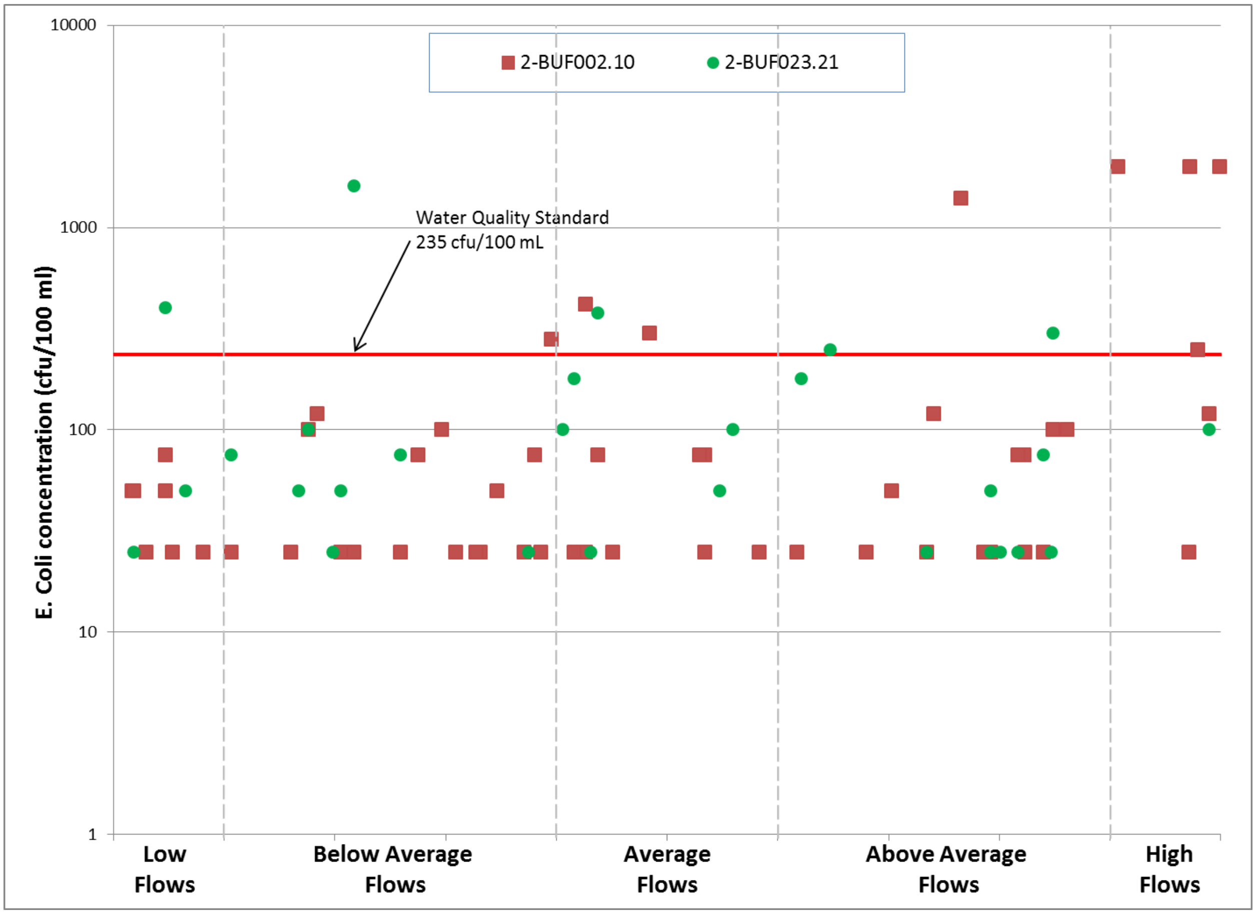

Figure 2.6. Flow conditions and *E. coli* concentrations for Buffalo River.

In Buffalo River (Figure 2.6), the monitored data at stations 2-BUF002.10 and 2-BUF023.21 reveal that exceedances of the water quality standard occur across all flow conditions, indicating that *E. coli* concentrations exceeding the water quality standard are both runoff based and directly deposited into the stream. The monitored data at station 2-MIN002.25 on Mill Creek, station 2-TNR000.25 on Turner Creek, and station 2-RTD003.08 on Rutledge Creek (Figure 2.7) also show exceedances of the water quality standard across flow conditions, indicating that bacteria concentrations exceeding the water quality standard are both runoff based and directly deposited into the stream.

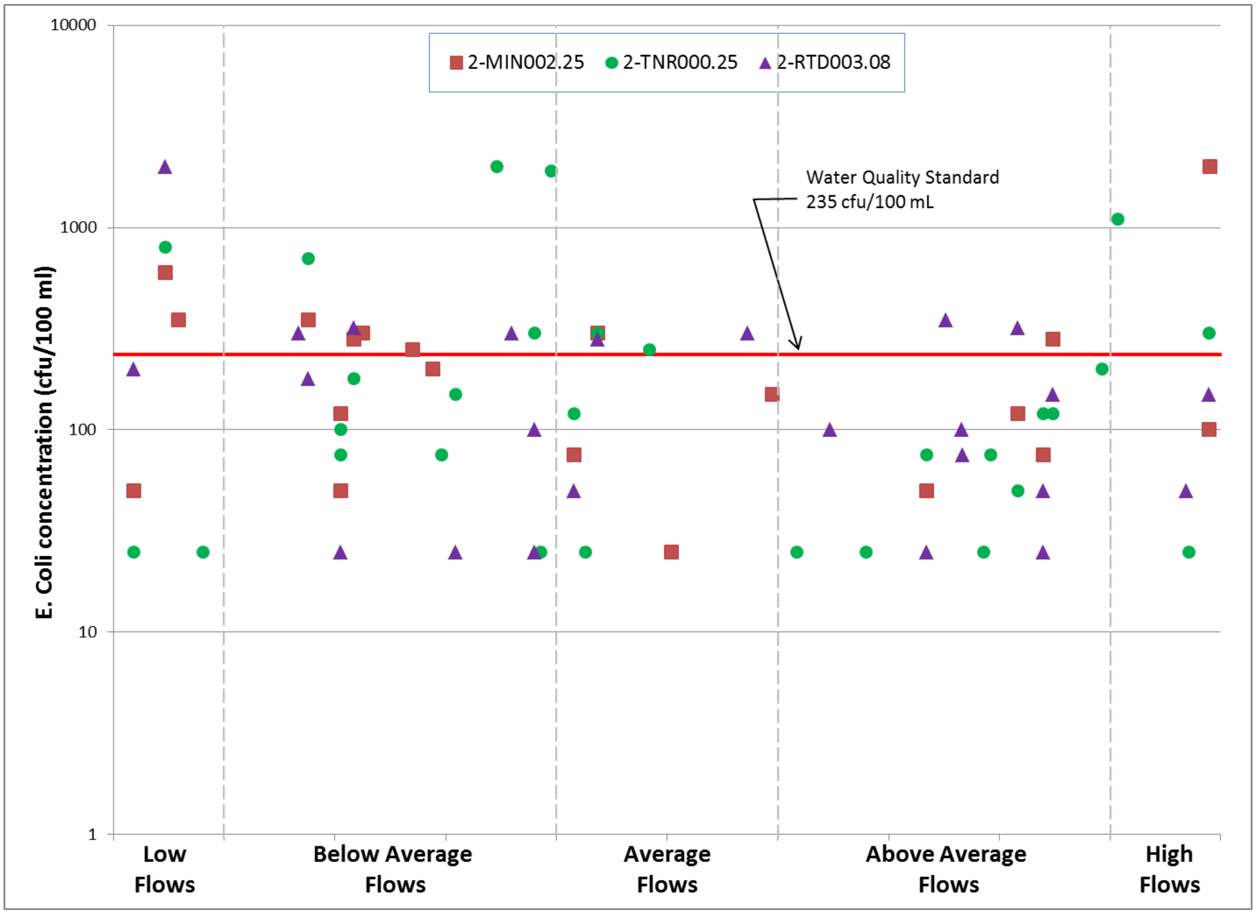

Figure 2.7. Flow conditions and *E. coli* concentrations for Mill Creek, Turner Creek, and Rutledge Creek.

Chapter 3: Source Assessment of Fecal Coliform

Fecal coliform sources and production rates in the Tye River watershed were assessed using information from the following sources: VADEQ, VADCR, Virginia Department of Game and Inland Fisheries (VADGIF), Virginia Cooperative Extension (VCE), Natural Resources Conservation Service (NRCS), the Thomas Jefferson Soil and Water Conservation District (SWCD), the Robert E. Lee SWCD, public participation, watershed reconnaissance and monitoring, published information, and professional judgment. Potential nonpoint sources of fecal coliform in the Tye River watershed are summarized in Table 3.1.

Table 3.1. Potential fecal coliform sources and daily fecal coliform production by source for existing conditions in the Tye River watershed.

Potential Source	Population	Fecal coliform produced (x 10^6 cfu/head/day)
Humans (permanent)	16089	2,000[a]
Beef Cattle[b]	12450	8,556[a]
Goats	1033	12,000[d]
Sheep	489	12,000[d]
Horses	450	420[d]
Poultry (broilers)	73000	89
Pets	7488	450[c]
Deer	11935	350
Raccoons	4569	50
Muskrats	275	25[e]
Beavers	300	0.2
Ducks	522	2,400
Geese	662	800
Wild Turkeys	1368	93
Otters	64	0.2

[a] Source: Geldreich (1978)
[b] Cow-calf pairs
[c] Source: Weiskel *et al*. (1996)
[d] Source: ASAE(1998)
[e] Source: Yagow (2001)

Point sources of fecal coliform bacteria in the Tye River watershed include three sewage treatment plants, a fish cultural station and one single family domestic sewage discharges (Table 3.2). Virginia issues Virginia Pollutant Discharge Elimination System (VPDES) permits for point sources of pollution. In Virginia, point sources that treat human waste are required to maintain an *E. coli* concentration of 126 cfu/100 mL or less in their effluent. In allocation scenarios for bacteria, load for each permitted point source was calculated as the allowable point source discharge concentration of 126 cfu/100 mL at their facility's maximum design flow rate.

Table 3.2. VPDES permitted facilities discharging into streams of the Tye River watershed.

Permit Number	Facility Name	Sub-watershed	Design Flow (mgd*)	Permitted *E. coli* Conc. (cfu/100 mL)	*E. coli* Load (cfu/year)
VA0031321	Rutledge Creek STP	32	0.4	126	6.97×10^{11}
VA0072991	Camp Blue Ridge STP	20	0.25	126	4.35×10^{11}
VA0091243	Montebello Fish Cultural Station	20	0.3875	126	6.75×10^{11}
VA0089729	Nelson County STP	11	0.22	126	3.83×10^{11}
VAG408143	Single Family Home	20	0.001	126	1.74×10^{9}

*million gallons per day

In addition to the permitted point source discharges, there is currently one Municipal Separate Storm Sewer System (MS4) permit (VAR040115) issued to the Virginia Department of Transportation (VDOT) within the Rutledge Creek watershed. This permit covers areas of land with stormwater runoff that discharges to surface waters. The land area within the permit boundaries has bacteria from residential sources (pet, human, and wildlife) which can be present in runoff.

3.1. Summary: Contributions from All Sources

The inventory of sources in the Tye River watershed includes humans (failing septic systems and straight pipes), pets, beef cattle (direct manure deposition to streams and on pasture), land application of solid manure (cattle and poultry), land application of biosolids, sheep/goats, horses, poultry and wildlife. Extensive detail on the inventory of sources is given in Appendix B. An estimate of the summary of the contribution by the different direct nonpoint sources to the annual fecal coliform loading to the streams is given in Table 3.3. The estimated distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.3.

From Table 3.3, it is clear that nonpoint source loadings to the land surface are greater than direct nonpoint source loadings to the stream. Pastures receive the greatest portion of this load, at 92%. However, factors such as precipitation amount and pattern, die-off rates, manure application activities, type of waste, and proximity to the streams impact the amount of fecal coliform from upland areas that reaches the streams. Due to their nature, direct nonpoint source loadings to streams are not modified before transmission to the stream. The HSPF model discussed in Chapter 4 considers these factors when estimating fecal coliform loadings in the receiving waters.

Table 3.3. Estimated annual fecal coliform loadings to the stream and the various land use categories for the Tye River watershed.

Source	Fecal coliform loading ($x10^{12}$ cfu/yr)	Percent of total loading
Direct loading to streams		
Livestock in stream	328	0.5%
Wildlife in stream	187	0.3%
Straight pipes	40	0.1%
Point Sources	3.5	<0.1%
Loading to land surfaces		
Cropland	152	0.2%
Pasture	63,219	92%
Residential	3161	4.6%
Forest	1613	2.3%
Total	**68,704**	

Chapter 4: Modeling Process for Bacteria TMDL Development

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and in-stream water quality conditions. Once this relationship is developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutants and cause the impairment of the waterbody of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and computer simulation models. In this chapter, the modeling process, input data requirements, and model calibration procedure and results are discussed.

4.1. Model Description

The TMDL development process requires the use of a watershed-based model that integrates both point and nonpoint sources and simulates in-stream water quality processes. The Hydrologic Simulation Program – FORTRAN (HSPF) version 12 (Bicknell et al., 2005; Duda et al., 2001) was used to model fecal coliform transport and fate in the Tye River watershed. The ArcGIS 10 GIS software was used to display and analyze landscape information for the development of input for HSPF.

The HSPF model simulates nonpoint source runoff and pollutant loadings, performs flow routing through streams, and simulates in-stream water quality processes. HSPF estimates runoff from both pervious and impervious parts of the watershed and stream flow in the channel network. The sub-module PWATER within the module PERLND simulates runoff, and hence, estimates the water budget, on pervious areas (e.g., agricultural land). Runoff from impervious areas is modeled using the IWATER sub-module within the IMPLND module. The simulation of flow through the stream network is performed using the sub-modules HYDR and ADCALC within the module RCHRES. While HYDR routes the water through the stream network, ADCALC calculates variables used for simulating convective transport of the pollutant in the stream. Fate of fecal coliform on pervious and impervious land segments is simulated using the PQUAL (PERLND module) and IQUAL (IMPLND module) sub-modules, respectively. Fate of fecal coliform in stream water is simulated using the general constituent pollutant (GQUAL) sub-module within the RCHRES module. Fecal coliform bacteria are simulated as dissolved pollutants in the GQUAL sub-module.

4.2. Model Calibration and Validation

Model calibration is the process of selecting model parameters that provide an accurate representation of the watershed. In this section, the procedures followed for calibrating the hydrology and water quality components of the Hydrological Simulation Program-FORTRAN (HSPF) model are discussed.

4.2.1. Hydrology

USGS monitors average daily flow rates on the Tye River at station 02027000, at the outlet of sub-watershed 13 and on Piney River at station 02027500 at the outlet of sub-watershed 24. The drainage area contributing to the Tye River Station is 93 mi^2, and 47.7 mi^2 to the Piney River Station. The consistent period of record at station 02027000 extends from October 1938 to present (April 2013 at time of writing), with an average flow rate of 284 cfs (USGS, 2013). The consistent period of record at station 02027500 extends from October 1949 to present (April 2013 at time of writing), with an average flow rate of 167 cfs (USGS, 2013). The Hydrology Statistics Calculator (HSC) decision support system developed by the Center for Watershed Studies, Biological Systems Engineering, Virginia Tech was used to calibrate the hydrologic portion of HSPF for Tye River and Piney River. Virginia DEQ criteria for evaluating the accuracy of the flow simulation were used in the calibration for Tye River and Piney River. After calibration, all DEQ criteria listed were met (see Tables 4.1 to 4.4).

The hydrologic calibration period (Tye River and Piney River) was January 1, 1991 to December 31, 1995. The hydrologic validation period (Tye River and Piney River) was from January 1, 1996 to December 31, 2000. The output from the HSPF model for both calibration and validation was daily average flow in cubic feet per second (cfs). Calibration parameters were adjusted within the recommended range (USEPA, 2000). The simulated flow for both the calibration and validation matched the observed flow well, as shown in Figure 4.1 and Figure 4.2 (Tye River); Figure 4.3 and Figure 4.4 (Piney River). Additional detail on hydrologic calibration and validation results (representative years, representative storms and cumulative frequency curves) is given in Appendix C.

Selected diagnostic output from the HSC program is listed in Table 4.1 and Table 4.2 (Tye River); Table 4.3 and Table 4.4 (Piney River). The total winter runoff and total summer runoff errors are considered in the HSC term 'seasonal volume error'. The errors for seasonal volume error were 6.7% for the calibration period and -1.9% for the validation period (Tye River); -0.5% for the calibration period and -9.2% for the validation period (Piney River); all are within the required range of 10%.

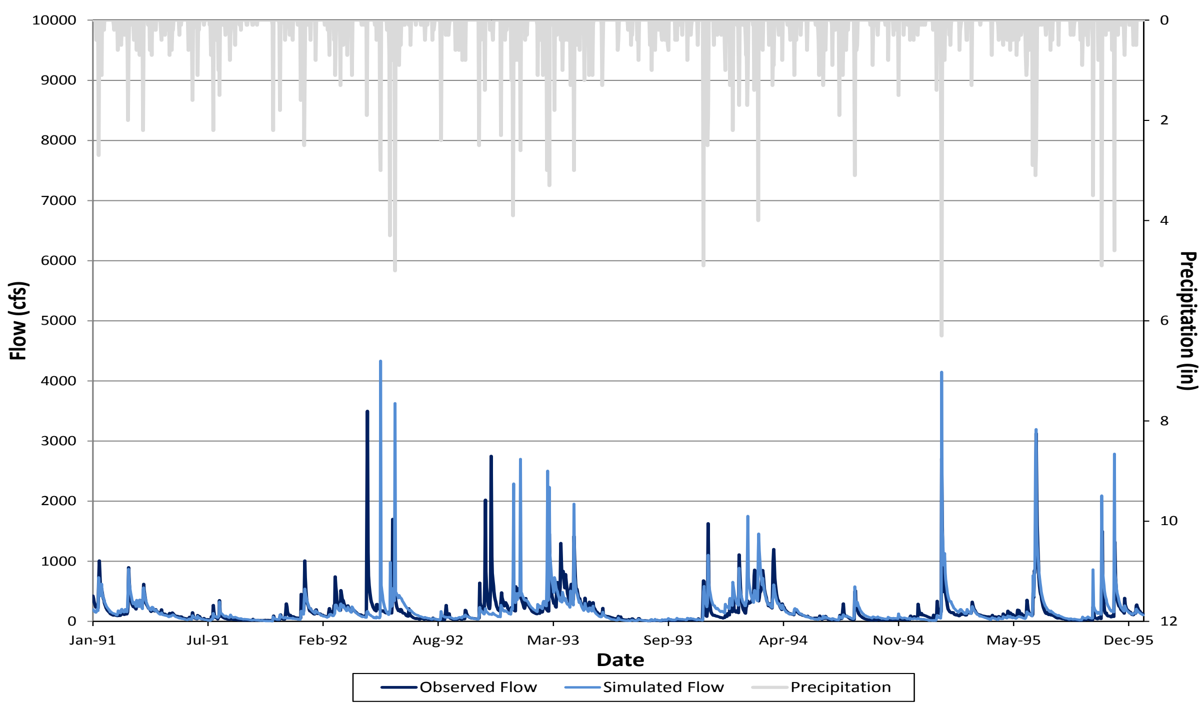

Figure 4.1. Observed and simulated flows and precipitation for Tye River for the calibration period.

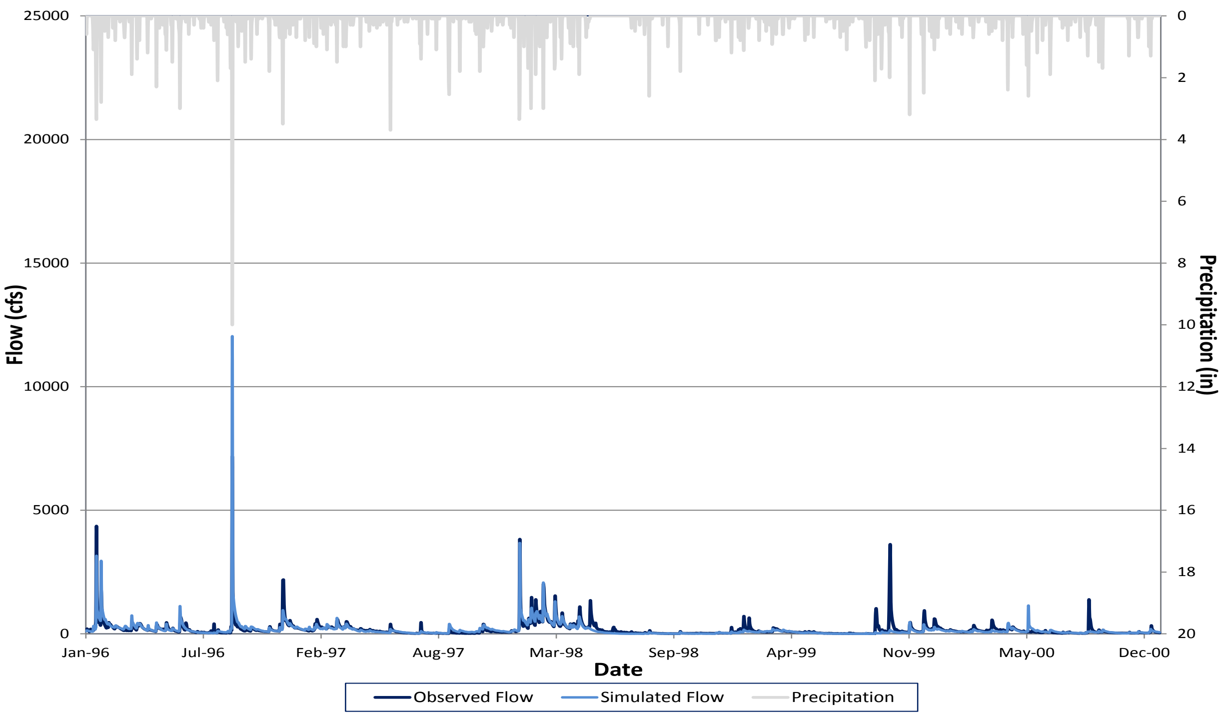

Figure 4.2. Observed and simulated flows and precipitation for Tye River during the validation period.

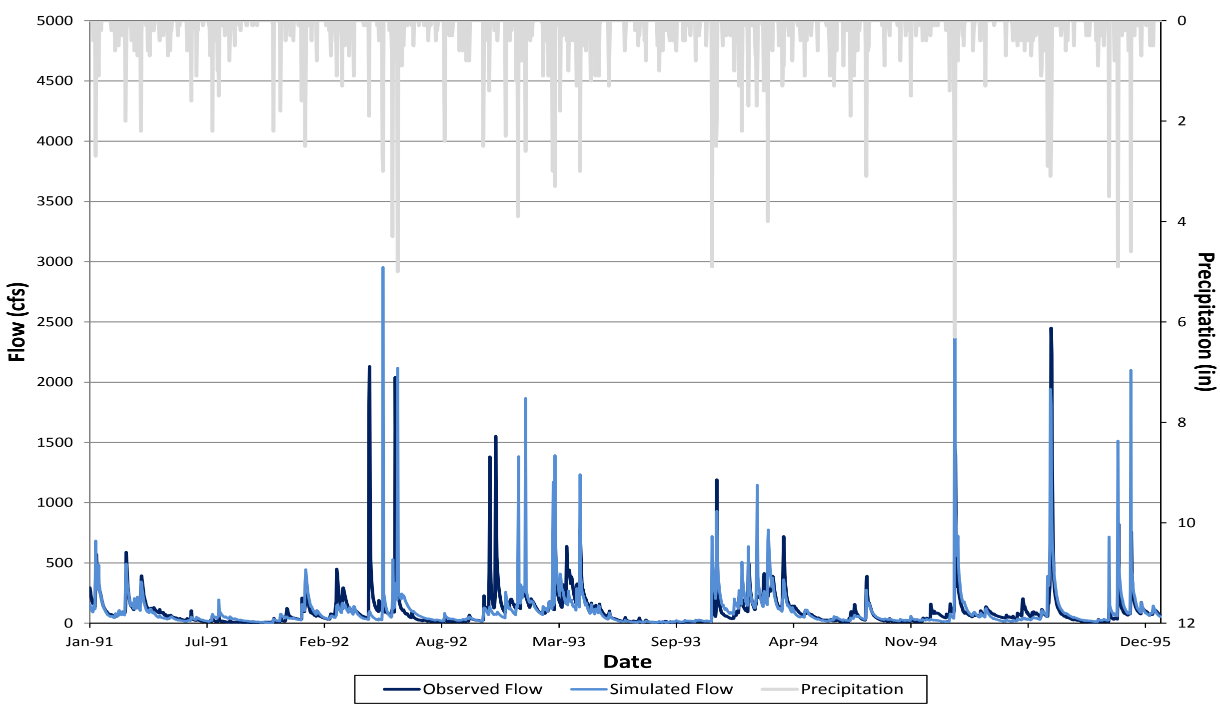

Figure 4.3. Observed and simulated flows and precipitation for Piney River for the calibration period.

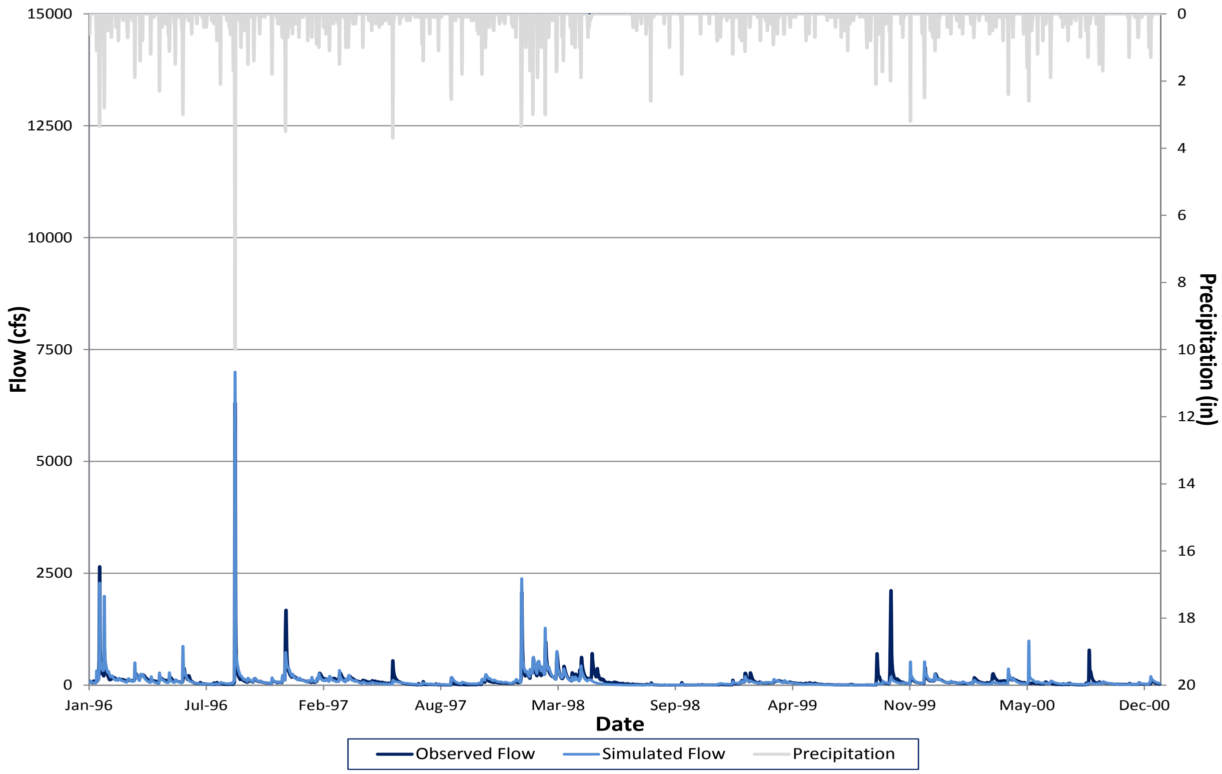

Figure 4.4. Observed and simulated flows and precipitation for Tye River during the validation period.

Table 4.1. Summary statistics for the calibration period for Tye River.

	Simulated	Observed	Error (%)	Criterion
Total Runoff (in)	134.030	127.400	+5.2	10%
Average Annual Total Runoff (in)	26.805	25.479	+5.2	10%
Total of Highest 10% of flows (in)	56.183	52.858	+6.3	15%
Total of Lowest 50% of flows (in)	18.212	17.771	+2.5	10%
Total Winter Runoff (in)	45.641	40.017	+14.1	na
Total Summer Runoff (in)	25.214	20.874	+20.8	na
Coefficient of Determination, r^2	0.37			

na = not applicable; these are not criteria directly considered by HSC

Table 4.2. Summary statistics for the validation period for Tye River.

	Simulated	Observed	Error (%)	Criterion
Total Runoff (in)	116.13	126.44	-8.2	10%
Average Annual Total Runoff (in)	23.227	25.289	-8.2	10%
Total of Highest 10% of flows (in)	51.193	55.077	-7.1	15%
Total of Lowest 50% of flows (in)	15.405	16.654	-7.5	10%
Total Winter Runoff (in)	46.596	49.817	-6.5	na
Total Summer Runoff (in)	9.979	10.89	-8.4	na
Coefficient of Determination, r^2	0.69			

na = not applicable; these are not criteria directly considered by HSC

Table 4.3. Summary statistics for the calibration period for Piney River.

	Simulated	Observed	Error (%)	Criterion
Total Runoff (in)	148.19	147.16	+0.7	10%
Average Annual Total Runoff (in)	29.637	29.432	+0.8	10%
Total of Highest 10% of flows (in)	66.757	63.055	+5.9	15%
Total of Lowest 50% of flows (in)	19.402	18.322	+5.9	10%
Total Winter Runoff (in)	54.017	47.65	+13.4	na
Total Summer Runoff (in)	28.122	24.916	+12.9	na
Coefficient of Determination, r^2	0.30			

na = not applicable; these are not criteria directly considered by HSC

Table 4.4. Summary statistics for the validation period for Piney River.

	Simulated	Observed	Error (%)	Criterion
Total Runoff (in)	128.94	139.85	-7.8	10%
Average Annual Total Runoff (in)	25.788	27.97	-7.8	10%
Total of Highest 10% of flows (in)	57.629	60.855	-5.3	15%
Total of Lowest 50% of flows (in)	17.855	17.951	-0.5	10%
Total Winter Runoff (in)	54.318	51.316	+5.8	na
Total Summer Runoff (in)	11.73	12.132	-3.3	na
Coefficient of Determination, r^2	0.15			

na = not applicable; these are not criteria directly considered by HSC

The calibrations met all the acceptance criteria in both the calibration and the validation period. This indicates that the developed hydrologic model provides an acceptable prediction of Tye River and Piney River flows.

4.2.2. Water Quality

The water quality calibration for the Tye River watershed was performed at an hourly time step using the HSPF model. Observations of bacterial water quality were available for 11 stations throughout the watershed, as shown in Figure 2.1 and discussed in Section 2.7. Thus, VADEQ monitoring stations 2-TYE020.67, 2-PYN005.29 and 2-BUF002.10 were the only stations used for calibration. All of the above stations had a large enough dataset that allowed for both calibration and validation using *E. coli* data. As a validation, the *E. coli* predictions from the model were visually compared with *E. coli* data collected at eight additional VADEQ stations: 2-HAT000.14, 2-TYE008.77, 2-RKR000.20, 2-TYE000.30, 2-BUF023.21, 2-MIN002.25, 2-RTD003.08 and 2-TNR00.25.

The period of January 1, 2007 to June 30, 2010 was selected for calibration of 2-TYE020.67 and 2-PYN005.29. For 2-BUF002.10, the period of January 1, 2008 to June 30, 2010 was used for calibration. The validation period for *E. coli* at all stations varied between the periods of January 1, 2002 to June 30, 2010 (based on data availability for individual stations). Output from the HSPF model was generated as an hourly time series and daily average time series of *E. coli* concentration at the sub-watershed outlets that correspond to the locations of stations TYE020.67, 2-PYN005.29, 2-BUF002.10, 2-HAT000.14, 2-TYE008.77, 2-RKR000.20, 2-TYE000.30, 2-BUF023.21, 2-MIN002.25, 2-RTD003.08 and 2-TNR00.25.

To represent the *E. coli* concentrations during calibration, validation and later during allocation, the VADEQ *E. coli* translator (Eqn. 4.2) was implemented using the GENER block in HSPF to calculate instream *E. coli* concentration. The geometric mean of *E. coli* concentrations was calculated on a monthly basis.

$$\log_2 EC(cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC(cfu/100mL) \qquad [4.2]$$

Observed data in the Tye River watershed were typically collected through grab samples collected on a monthly or bimonthly basis (at best). Because it is not practical to expect such data to exactly match an average simulated value on a specific day, other methods of comparison are needed. The strongest method of comparison is the use of the minimum and maximum simulated values – the observed data should fall roughly within the range of values simulated near the date of observed data collection. Other parameters to consider are violation rate, averages, medians, geometric means, etc.

Calibration

Initial model predictions of fecal coliform concentrations were high. Several input parameters were altered during the calibration process. These parameters included: the washoff factor (WSQOP); fecal coliform production rates for livestock, human, pets, and wildlife; and the first order decay rate (FSTDEC). Once these adjustments had been made the fecal coliform predictions from HSPF acceptably matched the simulated data. The final goodness-of-fit measures for the calibration at the monitoring stations (2-TYE020.67, 2-PYN005.29 and 2-BUF002.10) are listed in Table 4.5, Table 4.6 and Table 4.7. A graphical comparison between observed and simulated *E. coli* concentrations is displayed in Appendix C. The water quality calibration was considered acceptable.

Table 4.5. Water quality calibration statistics for Tye River at station 2-TYE020.67 (Nelson County)

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	81	269	75	14
Simulated	109	198	134	22

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection.

Table 4.6. Water quality calibration statistics for Piney River at station 2-PYN005.29 (Amherst County/Nelson County)

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	50	101	35	13
Simulated	91	180	100	22

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection.

Table 4.7. Water quality calibration statistics for Buffalo River at station 2-BUF002.10 (Amherst County)

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	93	331	75	24
Simulated	68	93	59	12

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection.

Validation

After the calibration of Tye River at VADEQ monitoring stations 2-TYE020.67, 2-PYN005.29 and 2-BUF002.10, the model output was compared to *E. coli* data from stations 2-TYE020.67, 2-PYN005.29 and 2-BUF002.10 for a different period (2-TYE020.67 and 2-PYN005.29: January 1, 2002 to December 31, 2006; 2-BUF002.10: January 1, 2005 to December 31, 2007) as a validation to ensure the calibrated input parameters were appropriate. The goodness-of-fit statistics for the validation run are listed in Table 4.8, Table 4.9 and Table 4.10. The simulated concentrations varied with the seasonal trend. Based on the goodness-of-fit parameter values both the water quality calibration and validation for Tye River at monitoring stations 2-TYE020.67, 2-PYN005.29 and 2-BUF002.10 were considered acceptable (graphical comparisons are illustrated in Appendix C).

Table 4.8. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Tye River at station 2-TYE020.67 (Nelson County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	50	110	10	16
Simulated	78	240	3	17

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection.

Table 4.9. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Piney River at station 2-PYN005.29 (Amherst County/Nelson County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	66	127	60	16
Simulated	70	105	75	14

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection.

Table 4.10. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Buffalo River at station 2-BUF002.10 (Amherst County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	41	57	25	6
Simulated	72	114	55	18

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection.

Additional 'validation' included visually comparing simulated *E. coli* concentrations with observed *E. coli* data from eight stations: 2-HAT000.14, 2-TYE008.77, 2-RKR000.20, 2-TYE000.30, 2-BUF023.21, 2-MIN002.25, 2-RTD003.08 and 2-TNR00.25. The translated and observed *E. coli* data were tabulated (Tables 4.11 – Table 4.18) to verify that the simulated *E. coli* concentrations approximated the observed values. The validation period between was January 2004 through June 2010 (based on data available at individual stations). The simulated data match well with the observed *E. coli* concentrations (graphical comparisons are illustrated in Appendix C).

Table 4.11. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Hat Creek at station 2-HAT000.14 (Nelson County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	193	252	250	53
Simulated	189	215	215	35

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

Table 4.12. Summarized goodness-of-fit measures for simulated and observed E. coli concentrations for the validation period for Tye River at station 2-TYE008.77 (Nelson County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	55	134	40	15
Simulated	97	276	65	22

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

Table 4.13. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Rucker Run at station 2-RKR000.20 (Nelson County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	81	165	50	33
Simulated	80	160	91	25

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

Table 4.14. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Tye River at station 2-TYE000.30 (Nelson County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	52	103	25	22
Simulated	61	216	132	14

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

Table 4.15. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Buffalo River at station 2-BUF023.21 (Nelson County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	91	194	75	22
Simulated	122	131	116	29

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

Table 4.16. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Mill Creek at station 2-MIN002.25 (Amherst County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	200	341	250	54
Simulated	218	357	286	46

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

Table 4.17. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Rutledge Creek at station 2-RTD003.08 (Amherst County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	178	212	215	50
Simulated	112	149	150	31

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

Table 4.18. Summarized goodness-of-fit measures for simulated and observed *E. coli* concentrations for the validation period for Turner Creek at station 2-TNR000.25 (Amherst County).

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	131	373	120	33
Simulated	169	189	177	38

* Simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

Chapter 5: TMDL Allocations

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991).

5.1. Background

The objective of the bacteria TMDLs for the Tye River watershed was to determine what reductions in fecal coliform and *E. coli* loadings from point and nonpoint sources are required to meet state water quality standards. The state water quality standard for *E. coli* used in the development of the TMDL was a calendar-month geometric mean of 126 cfu/100 mL. The TMDL considers all significant sources contributing *E. coli* to the impaired streams. The sources can be separated into nonpoint and point sources. The different sources in the TMDL are defined in the following equation:

$$TMDL = WLA_{total} + LA + MOS \qquad [5.1]$$

Where:

WLA_{total} = waste load allocation (point source contributions, including future growth)

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

A TMDL accounts for critical conditions, seasonal variations and must include a margin of safety (MOS).

When developing a bacterial TMDL, the required bacteria load reductions are modeled by decreasing the amount of bacteria running off the land surface that reach the stream or decreasing the amount of bacteria directly deposited in the stream; these reductions are presented in the tables in the following sections. The reductions called for in the following sections indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions shown in these sections are not intended to infer that agricultural producers should reduce their herd size, or limit the use of manures as fertilizer or soil conditioner.

Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, eliminating sewage spills, and other appropriate measures included in the TMDL Implementation Plan.

5.1.1. Margin of Safety

To allocate loads while protecting the aquatic environment, a MOS needs to be considered. A MOS is typically expressed either as unallocated assimilative capacity or as conservative analytical assumption use in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed controls). In the TMDL calculation, the MOS can either be explicitly stated as an additional separate quantity, or implicitly stated, as in conservative assumptions.

5.1.2. Accounting for Critical Conditions and Seasonal Variations

EPA regulations at 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when they are most vulnerable. Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and help to identify the actions that may have to be undertaken to meet water quality standards.

A period of four years was used for allocation modeling. Observed meteorological data from the Montebello weather station were extracted for 2002-2006 and used in the allocation simulations. These particular rainfall years were selected because they incorporate average rainfall, low rainfall, and high rainfall; and the climate during these years caused a wide range of hydrologic events including both low and high flow conditions. Seasonal variations involved changes in surface runoff, stream flow, and water quality as a result of hydrologic and climatologic patterns. The bacteria loading estimates and reduction targets are accounted using this simulation by the model.

5.2. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Table 5.1) shows that contributions from livestock direct deposits are the primary source of *E. coli* to the stream. Contributions from pervious land sources also constitute a significant portion of the in-stream concentrations in Tye River. Contributions from wildlife direct deposits are also noticeable contributors to the mean daily *E. coli* concentration. The results in this table were taken as the average daily contributions for the allocation simulation period, irrespective of the magnitude of the concentration or the flow rate (factors that were considered in the earlier section detailing the source breakdown used in the calibration). Table 5.1 gives an idea of what sources will be the dominant contributors to the instantaneous *E. coli* concentrations, and thus what sources will control the violations of the single sample criterion: loadings from livestock direct deposit will violate the single sample criterion by themselves in all of the impaired segments in the watershed. Wildlife direct deposit will violate the single sample criterion by themselves in Mill Creek, Turner Creek, Rutledge Creek, Hat Creek and Rucker Run. Although the overall contribution from pervious land sources is not as high as loading from livestock direct deposits, it dominates the concentration during high flow events and in fact, by itself, will violate the instantaneous standard multiple times throughout the allocation period.

Table 5.1. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in Tye River.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	20	22%
Direct nonpoint source loadings to the stream from wildlife	23	24%
Direct nonpoint source loadings to the stream from livestock	42	46%
Interflow and groundwater contribution	0.7	<1%
Straight-pipe discharges to stream	6	6%
Nonpoint source loadings from impervious land segments	0.1	<1%
Permitted point source loadings	0.6	<1%
All Sources	92	

The contribution of each of the sources listed in Table 5.1 to the calendar-month geometric mean *E. coli* concentration at the outlet of Tye River is shown in Figure 5.1. The contributions from livestock direct deposit dominate the calendar-month geometric mean concentration. The contributions from wildlife direct deposit are also a significant factor in Tye River. The cyclic nature of livestock direct deposit contributions is due to increased time spent in streams by livestock during summer months, combined with lower flow volumes; these two factors combine to increase bacteria concentrations during the summer months. Contributions from pervious land surfaces also contribute a significant amount to the geometric mean concentration. It is evident that violations of the calendar-month geometric mean criterion will be most controlled by contributions from direct in-stream sources, and further, that it will be impossible to meet the calendar-month geometric mean criterion without reducing contributions from livestock direct deposit, as this source alone violates the criterion during the allocation period. Contributions from wildlife direct deposit alone will also violate the calendar-month geometric mean criterion in Mill Creek, Turner Creek, Rutledge Creek, Hat Creek and Rucker Run, and therefore must be reduced in these watersheds to meet the calendar-month geometric mean standard.

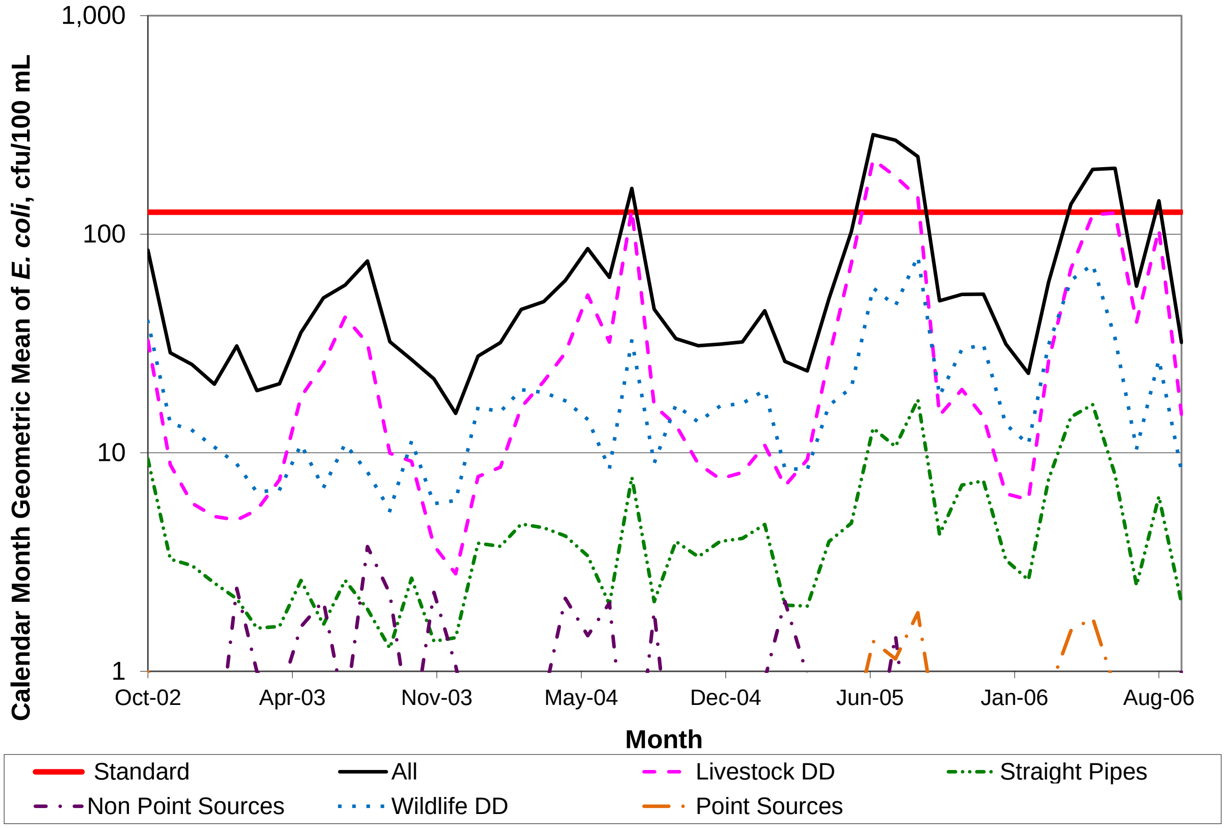

Figure 5.1. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration at the outlet of Tye River for existing conditions.

5.3. Future Conditions

Although the Nelson County Comprehensive Plan (adopted October 8, 2002) and Amherst County Comprehensive Plan (adopted June 21, 2007) outline potential growth in the Tye River watershed, this potential growth was minimal. Therefore, allocation scenarios for the load allocation (LA) were developed using existing conditions in the watershed. Future growth of permitted sources in the watersheds is allocated in the WLA.

5.4. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean concentration less than 126 cfu/100 mL. The scenarios and results are summarized in Tables 5.2 – 5.9 for Hat Creek, Piney River, Rucker Run, Mill Creek, Rutledge Creek, Turner Creek, Buffalo River and Tye River; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. The recommended scenarios are highlighted in yellow in Tables 5.2 – 5.9. Note that only minor are reductions required in loads from cropland; this is because the cropland areas are minimal in this watershed. Because there was such a small load on cropland compared to other sources, changing the reductions from 100% (in the unsuccessful runs) to 0% (in the successful runs) had minimal effect on attainment of the standard.

Scenarios labeled “1” are shown in Tables 5.2 – 5.9 to illustrate that there is a need for reductions in wildlife loads in Mill Creek, Turner Creek, Rutledge Creek, Hat Creek and Rucker Run to meet the water quality standard. Successful scenarios labeled “2” show the minimum modeled reductions needed to attain compliance with the *E. coli* standard. However, the true measure of water quality improvement in this watershed will not be based on modeled results, but rather on the results of in-stream monitoring.

Table 5.2. Bacteria allocation scenarios for the Mill Creek watershed (Amherst County).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenarios							
Baseline Conditions	0	0	0	0	0	0	52
1	100	100	100	100	100	0	4
Successful Scenario							
2	99	20	5	100	0	35	0

* does not include loads from failing septic systems

Table 5.3. Bacteria allocation scenarios for the Turner Creek watershed (Amherst County).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	38
1	100	100	100	100	100	0	4
Successful Scenarios							
2	99	30	5	100	0	30	0

* does not include loads from failing septic systems

Table 5.4. Bacteria allocation scenarios for the Rutledge Creek watershed (Amherst County).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	38
1	100	100	100	100	100	0	8
Successful Scenarios							
2	99	10	5	100	0	30	0

* does not include loads from failing septic systems

Table 5.5. Bacteria allocation scenarios for the Buffalo River watershed (Amherst County).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	17
1	100	100	100	100	100	0	0
Successful Scenarios							
2	90	5	5	100	0	0	0

* does not include loads from failing septic systems

Table 5.6. Bacteria allocation scenarios for the Piney River watershed (Amherst County/Nelson County).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	21
1	100	100	100	100	100	0	0
Successful Scenarios							
2	90	25	5	100	0	0	0

* does not include loads from failing septic systems

Table 5.7. Bacteria allocation scenarios for the Hat Creek watershed (Nelson County).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	44
1	100	100	100	100	100	0	6
Successful Scenarios							
2	99	25	5	100	0	30	0

* does not include loads from failing septic systems

Table 5.8. Bacteria allocation scenarios for the Rucker Run watershed (Nelson County).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	23
1	100	100	100	100	100	0	4
Successful Scenarios							
2	99	30	5	100	0	20	0

* does not include loads from failing septic systems

Table 5.9. Bacteria allocation scenarios for the Tye River watershed Nelson County).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	17
1	100	100	100	100	100	0	0
Successful Scenarios							
2	70	5	5	100	0	0	0

* does not include loads from failing septic systems

As a general rule, direct deposit sources (livestock, wildlife, and straight pipes) control violations of the calendar-month geometric mean standard. These sources control the constant inputs to the water body, and thus control the geometric mean of the daily average predictions over the entire month.

Loadings for the existing conditions and the chosen successful TMDL allocation scenario (2) are presented for nonpoint sources by land use in Table 5.10 – Table 5.17 and for direct nonpoint sources in Table 5.18 – Table 5.25.

Table 5.10. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Mill Creek (Amherst County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	3.4	<1	3.2	5
Pasture	1608	97	1287	20
Residential	40	2	12.4	69
Forest	12	<1	12	0
Total	1664		1314	21

Table 5.11. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Turner Creek (Amherst County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	4.6	<1	4.33	5
Pasture	1409	88	986	30
Residential	165	10	57	66
Forest	20	1	20	0
Total	1599		1067	33

Table 5.12. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Rutledge Creek (Amherst County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	7.4	<1	7.1	5
Pasture	2448	81	2203	10
Residential	514	17	205	60
Forest	59	2	59	0
Total	3028		2475	18

Table 5.13. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Buffalo River (Amherst County).

	Existing Conditions		Allocation Scenario	
Land use category	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	128	<1	122	5
Pasture	19188	91	18230	5
Residential	1311	6	524	60
Forest	366	2	366	0
Total	20993		19242	8

Table 5.14. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Piney River (Amherst County/Nelson County).

	Existing Conditions		Allocation Scenario	
Land use category	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	22	<1	21	5
Pasture	9811	94	7358	25
Residential	375	4	131	65
Forest	221	2	221	0
Total	10429		7731	26

Table 5.15. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Hat Creek (Nelson County).

	Existing Conditions		Allocation Scenario	
Land use category	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	6.8	<1	6.5	5
Pasture	4961	96	3721	25
Residential	115	2	48	58
Forest	78	2	78	0
Total	5161		3854	25

Table 5.16. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Rucker Run watershed (Nelson County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	21	<1	20	5
Pasture	7269	92	5088	30
Residential	418	5	188	55
Forest	199	3	199	0
Total	7907		5495	31

Table 5.17. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Tye River watershed (Nelson County).

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	152	<1	144	5
Pasture	63219	93	60058	5
Residential	3161	5	1264	60
Forest	1613	2	1613	0
Total	68145		63079	7

Table 5.18. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Mill Creek (Amherst County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	7.7	64	0.08	99
Straight Pipes	1.6	13	0	100
Wildlife in Streams	2.8	23	1.81	35
Total	12.1		1.89	84

Table 5.19. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Turner Creek (Amherst County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	9	62	0.09	99
Straight Pipes	1.6	11	0	100
Wildlife in Streams	4	27	2.78	30
Total	14.6		2.87	80

Table 5.20. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Rutledge Creek (Amherst County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	23	61	0.2	99
Straight Pipes	4	11	0	100
Wildlife in Streams	11	28	7.6	30
Total	38		7.8	80

Table 5.21. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Buffalo River (Amherst County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	106	58	11	90
Straight Pipes	11	6	0	100
Wildlife in Streams	65	35	65	0
Total	182		76	59

Table 5.22. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Piney River (Amherst County/Nelson County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	55	65	5.5	90
Straight Pipes	10	11	0	100
Wildlife in Streams	20	23	20	0
Total	85		25.5	70

Table 5.23. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Hat Creek (Nelson County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	26	58	0.26	99
Straight Pipes	7	15	0	100
Wildlife in Streams	12	27	8.4	30
Total	45		8.66	81

Table 5.24. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Rucker Run (Nelson County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	46	66	0.46	99
Straight Pipes	3	4	0	100
Wildlife in Streams	21	30	15	30
Total	70		15.46	78

Table 5.25. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Tye River (Nelson County).

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	328	59	98	70
Straight Pipes	40	7	0	100
Wildlife in Streams	187	34	187	0
Total	555		285	49

The fecal coliform allocation scenario loads presented in Tables 5.9 – 5.25 are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF-predicted mean daily fecal coliform concentrations.

5.5. Waste Load Allocation

There are five permitted VPDES facilities in the Tye River watershed (Table 3.2). One of these is a single family home and the load from this source was considered small relative to the load allocation. A WLA was assigned to the permitted point source facilities, three in the Tye River watershed (Camp Blue Ridge STP – VA0072991, Montebello Fish Cultural Station – VA0091243, Nelson County STP – VA0089729 and a Single Family Home – VAG408143) and one in the Rutledge Creek watershed (Rutledge Creek STP – VA0031321). The point sources were represented in the allocation scenario by their current permit conditions; no reductions were required from the point source in the TMDL. Current permit requirements are expected to result in attainment of the *E. coli* WLA as required by the TMDL. Point source contributions to bacteria concentrations, even in terms of maximum flow, are minimal. In addition, the point source facilities are required to discharge at or below the bacteria water quality criteria and therefore cannot cause a violation of those criteria without also violating the discharge permit. Because the permits for these facilities already protect against violating the bacteria water quality standard, there is no need to modify the existing permits.

There is one VDOT MS4 permit (VAR040115) for state maintained highways in a portion of the Rutledge Creek watershed, It is assumed that all impervious land area within the VDOT MS4 boundaries transport runoff that discharges into the surface waters. The *E. coli* loads from the impervious areas within the limits of the MS4 permit are included in the WLA.

To account for future growth to the impaired segments with no permitted sources (i.e., Hat Creek, Piney River, Rucker Run, Mill Creek, Turner Creek and Buffalo River), 2% of the TMDL was added to the waste load allocation. The existing WLA in the watershed represented ≤ 10% of the TMDL. Therefore, a scenario to account for future growth was set at 2% of the TMDL for permitted operations in the Tye River and Rutledge Creek watersheds. The new scenario results in no violations of geometric mean standard. Therefore, it is assumed that future growth in point source dischargers with a consistent permitted bacteria concentration of 126 cfu/100 mL *E. coli* will not cause additional violations of the water quality standards.

Table 5.26. Estimated annual WLA for *E. coli* loadings (cfu/yr) at the watershed outlet used for the Tye River bacteria TMDL.

Permit Number	WLA
VA0072991	4.35×10^{11}
VA0091243	6.75×10^{11}
VA0089729	3.83×10^{11}
VAG408143	1.74×10^{9}
Future Growth	1.18×10^{13}
WLA_{Total}	1.33×10^{13}

Table 5.27. Estimated annual WLA for *E. coli* loadings (cfu/yr) at the watershed outlet used for the Rutledge Creek bacteria TMDL.

Permit Number	WLA
VA0031321	6.97×10^{11}
VAR040115	8.54×10^{9}
Future Growth	4.44×10^{11}
WLA_{Total}	1.15×10^{12}

5.6. Summary of the TMDL Allocation Scenarios for Bacteria

TMDLs for *E. coli* have been developed for Hat Creek, Piney River, Rucker Run, Mill Creek, Rutledge Creek, Turner Creek, Buffalo River and Tye River. The TMDLs address the following issues:

1. The TMDLs meet the calendar-month geometric mean water quality standard.
2. Because *E. coli* loading data were not available to quantify nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator equation was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations.
3. The TMDLs were developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.
5. Both high- and low-flow stream conditions were considered while developing the TMDLs. In the Tye River watershed, violations of the water quality standard were caused during both low stream flow and high stream flow; because the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions.
6. Both the flow regime and bacteria loading to the streams are seasonal. The TMDLs account for these seasonal effects.

Using equation 5.1, the summary of the bacteria TMDLs for Hat Creek, Piney River, Rucker Run, Mill Creek, Rutledge Creek, Turner Creek, Buffalo River and Tye River for the selected allocation scenarios is given in Table 5.28.

Table 5.28. Maximum annual *E. coli* loadings (cfu/yr) at the impaired watershed outlets in the Tye River watershed.

Impairment	WLA_{total}	LA	MOS*	TMDL
Hat Creek	6.02×10^{11}	2.86×10^{13}	--	2.92×10^{13}
Piney River	2.44×10^{12}	1.20×10^{14}	--	1.22×10^{14}
Rucker Run	1.32×10^{12}	6.47×10^{13}	--	6.60×10^{13}
Mill Creek	2.08×10^{11}	9.98×10^{12}	--	1.02×10^{13}
Rutledge Creek	1.15×10^{12}	2.03×10^{13}	--	2.15×10^{13}
Turner Creek	1.57×10^{11}	7.71×10^{12}	--	7.87×10^{12}
Buffalo River	2.54×10^{12}	1.25×10^{14}	--	1.27×10^{14}
Tye River	1.33×10^{13}	5.75×10^{14}	--	5.88×10^{14}

*Implicit MOS

5.6.1. Daily *E. coli* TMDL

The USEPA has mandated that TMDL studies completed in 2007 and later include a daily maximum load as well as the average annual load shown in the previous section. The daily load was determined as the product of a representative flow rate from the watershed and the appropriate concentration criterion from the water quality standard. This section summarizes the daily maximum loads for Tye River.

Hydrologic Considerations

According to guidance from EPA (USEPA, 2006) it is necessary to assess the flow duration curve to determine an appropriate flow rate to use in the load calculation. EPA guidance suggests that the flow duration curve should be plotted using observed continuous flow data. Flow data from the USGS gage used in the hydrologic calibration were used to calculate the daily load. As is specified in the EPA guidance, the observed flows from Tye River were multiplied by the ratio of the impaired segments of the Tye River watershed area to the drainage area above the USGS gage. The flow rate corresponding to the 99^{th} percentile flow (that is, the flow rate exceeded by only 1% of the observed flows) was identified for the Tye River at the USGS gage as 1,134 cfs.

Daily Load

Setting a *maximum daily* load will help ensure that the annual loads given in Table 5.28 are appropriately distributed such that on any given day the single sample component of the bacteria water quality standard will be met. The loadings in the annual load tables, being of a long-term nature, will more directly assure compliance with the geometric mean component of the standard. Thus, the maximum daily load was computed as the product of the critical flow condition and the geometric mean criterion (126 cfu/100 mL). Since the annual WLA is already based on a maximum daily permitted flow and a maximum daily permitted concentration the daily WLA is calculated as the annual WLA divided by 365; the daily LA is then the TMDL less the WLA. The resulting daily maximum loadings are shown in Table 5.29. The actual maximum daily load is dependent upon flow conditions, and progress toward water quality improvement will be assessed against the numeric water quality criteria (126 cfu *E. coli*/100 mL for a calendar month geometric mean, and 235 cfu *E. coli*/100 mL for a single sample).

Table 5.29. Maximum daily *E. coli* loadings (cfu/day) at the watershed outlets.

Watershed	WLA_{total} †	LA	MOS*	TMDL
Hat Creek	1.65×10^{9}	7.29×10^{11}	-	7.31×10^{11}
Piney River	6.88×10^{9}	2.65×10^{12}	-	2.66×10^{12}
Rucker Run	3.62×10^{9}	1.88×10^{12}	-	1.89×10^{12}
Mill Creek	5.70×10^{8}	1.69×10^{11}	-	1.70×10^{11}
Rutledge Creek	3.15×10^{9}	6.65×10^{11}	-	6.68×10^{11}
Turner Creek	4.31×10^{8}	2.63×10^{11}	-	2.63×10^{11}
Buffalo River	6.96×10^{9}	3.85×10^{12}	-	3.86×10^{12}
Tye River	3.64×10^{10}	1.57×10^{13}	-	1.57×10^{13}

†the WLA will be implemented in accordance with permitting regulations
*Implicit MOS

Chapter 6: TMDL Implementation and Public Participation

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non-point sources in the stream (see Section 6.4.2). For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for non-point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/TMDL/TMDLImplementation/TMDLImplementationPlanGuidanceManual.aspx. With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

6.1. Staged Implementation

In general, Virginia intends for the required bacteria reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising best management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from straight pipe discharges and failing septic systems should be a primary implementation focus because of their health implications. These components could be implemented through education on septic tank pump-outs, a septic system installation/repair/replacement program, and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines and sewage spillage could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following Stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

6.2. Stage 1 Scenarios

The goal of the Stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the instantaneous criterion (235 cfu/100mL) are less than 10.5 percent while requiring no reductions from wildlife sources. The Stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. One successful scenario was selected for each of the impaired watersheds (Table 6.1).

Table 6.1. Allocation scenario for Stage 1 TMDL implementation for the Tye River watershed.

Impaired Segment	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %							% Violation of *E. coli* Single Sample Standard
	Livestock Direct Deposit	Loads from Cropland	Loads from Pasture	Straight Pipes & Failing Septic Systems	Non-Human Loads from Residential Areas	Wildlife Direct Deposit	Loads from Forested Areas	
Hat Creek	75	5	25	100	0	0	0	10
Piney River	40	5	25	100	0	0	0	10
Rucker Run	65	5	25	100	0	0	0	10
Mill Creek	80	5	20	100	0	0	0	10
Rutledge Creek	60	5	30	100	0	0	0	9
Turner Creek	65	5	30	100	0	0	0	10
Buffalo River	10	5	5	100	0	0	0	9
Tye River	10	5	5	100	0	0	0	6

6.3. Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts in Tye River and efforts aimed at restoring water quality in the James River.

6.4. Reasonable Assurance for Implementation

6.4.1. Follow-up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with VADEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the VADEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the Implementation Plan), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plan. Ancillary monitoring by citizens, watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/CitizenMonitoring.aspx.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

6.4.2. Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 “Guidance for Water Quality-Based Decisions: The TMDL Process.” The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the Virginia NPDES (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process, and with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

For the implementation of the TMDL’s LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the Water Quality Management Plans (WQMPs). Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board for inclusion in the appropriate WQMP, in accordance with the Clean Water Act’s Section 303(e) and Virginia’s Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the State Water Control Board (SWCB) adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on VADEQ's web site under http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/TMDL/Regulation.aspx.

6.4.3. Stormwater Permits

DEQ coordinates the State programs that regulate the management of pollutants carried by storm water runoff. VADEQ regulates storm water discharges associated with "industrial activities", discharges from construction sites, and from municipal separate storm sewer systems (MS4s).

It is the intent of the Commonwealth that TMDLs implement existing regulations and programs where they apply. Currently, there is one MS4 permitted in the Tye River watershed included in this study. More information is available on VADEQ's web site through the following link: http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/VSMPPermits/MS4Permits.aspx. Additional information on Virginia's Stormwater Management program can be found at http://www.deq.virginia.gov/Programs/Water/StormwaterManagement.aspx.

6.4.4. Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.5. Attainability of Primary Contact Recreation Use

In some streams for which TMDLs have been developed, including Tye River, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in wildlife load.

With respect to these potential reductions in bacteria loads attributed to wildlife, Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. However, if bacteria levels remain high and localized overabundant populations of wildlife are identified as the source, then measures to reduce such populations may be an option if undertaken in consultation with the Department of Game and Inland Fisheries (DGIF) or the United States Fish and Wildlife Service (USFWS). Additional information on DGIF's wildlife programs can be found at http://www.dgif.virginia.gov/wildlife/game/. While managing such overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address the overall issue of attainability of the primary contact criteria, Virginia proposed during its latest triennial water quality standards review a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria became effective on February 12, 2004 and can be found at
http://ftp.deq.virginia.gov/wqs/documents/WQS_eff_6JAN2011.pdf.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process.

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted primarily at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance populations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Section 6.1 above. VADEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

6.5 Public Participation

Public participation was solicited at every stage of TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. In July 2012, members of the Center for Watershed Studies at Virginia Tech traveled to Amherst County and Nelson County for a day trip around the impaired watersheds to become acquainted with them. Throughout the process, personnel from Virginia Tech contacted stakeholders and local agency personnel via telephone, email, and in person to acquire their input.

In Nelson County, numerous technical advisory committee meetings were held to inform stakeholders of the TMDL process and solicit feedback. These were held on June 12, 2012 (Nelson County Government Center, Lovingston, Virginia), September 10, 2012 (Massies Mill Ruritan Club, Roseland, Virginia), November 14, 2012 (Massies Mill Ruritan Club, Roseland, Virginia), March 26, 2013 (Massies Mill Ruritan Club, Roseland, Virginia) and April 3, 2013 (Massies Mill Ruritan Club, Roseland, Virginia). These meetings provided a forum for a group of interested stakeholders and agency personnel to provide detailed feedback on the estimates and methods used in these TMDLs. The first Public Meeting in Nelson County was held on July 9, 2012 at the Massies Mill Ruritan Club in Roseland, Virginia. The purpose of that meeting was to introduce the public to the TMDL process and to discuss the impairments identified on stream segments in these watersheds. The final Public Meeting in Nelson County was held on May 22, 2013 at the Massies Mill Ruritan Club in Roseland, Virginia to present the draft bacteria TMDL report for Hat Creek, Rucker Run, Piney River, and Tye River.

In Amherst County, technical advisory committee meetings were held on June 14, 2012, September 24, 2012, March 26, 2013, and April 17, 2013 at the Central Virginia Community College, Amherst, Virginia. The first Public Meeting was held on June 25, 2012 at the Central Virginia Community College, Amherst, Virginia. A final Public Meeting to present the draft bacteria TMDL report for Mill Creek, Turner Creek, Buffalo River and Rutledge Creek, and the draft sediment TMDL report for Long Branch and Buffalo River was held on April 25, 2013 at the Central Virginia Community College, Amherst, Virginia.

The public comment period on the Bacteria TMDL report for the Tye River watershed ended on June 24, 2013. Comments were received and addressed in the report.

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Appendix A: Glossary of Terms

Allocation
That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario
A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

Background levels
Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources)
A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Best Management Practices (BMP)
Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Bacteria Source Tracking
A collection of scientific methods used to track sources of fecal coliform.

Calibration
The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Die-off (of fecal coliform)
Reduction in the fecal coliform population due to predation by other bacteria as well as by adverse environmental conditions (e.g., UV radiation, pH).

Direct nonpoint sources
Sources of pollution that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: direct deposits of fecal material to streams from livestock and wildlife.

Failing septic system
Septic systems in which drain fields have failed such that effluent (wastewater) that is supposed to percolate into the soil, now rises to the surface and ponds on the surface

where it can flow over the soil surface to streams or contribute pollutants to the surface where they can be lost during storm runoff events.

Fecal coliform
A type of bacteria found in the feces of various warm-blooded animals that is used as indicator of the possible presence of pathogenic (disease causing) organisms. *E. coli* bacteria are a subset of this group found to more closely correlate with human health problems.

Geometric mean
The geometric mean is simply the nth root of the product of n values. Using the geometric mean lessens the significance of a few extreme values (extremely high or low values). In practical terms, this means that if you have just a few bad samples, their weight is lessened.

Mathematically the geometric mean, $\overline{x}_g$, is expressed as:

$$\overline{x}_g = \sqrt[n]{x_1 \cdot x_2 \cdot x_3 \ldots \cdot x_n}$$

where n is the number of samples, and x_i is the value of sample i.

HSPF (Hydrological Simulation Program-Fortran)
A computer-based model that calculates runoff, sediment yield, and fate and transport of various pollutants to the stream. The model was developed under the direction of the U.S. Environmental Protection Agency (EPA).

Hydrology
The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Instantaneous or Single Sample criterion
The instantaneous criterion or instantaneous water quality standard is the value of the water quality standard that should not be exceeded at any time. For example, the Virginia instantaneous water quality standard for *E. coli* is 235 cfu/100 mL. If this value is exceeded at any time, the water body is in violation of the state water quality standard.

Load allocation (LA)
The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)
A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models).

Model
Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Nonpoint source
Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Pathogen
Disease-causing agent, especially microorganisms such as bacteria, protozoa, and viruses.

Point source
Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution
Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Reach
Segment of a stream or river.

Runoff
That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system
An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives liquid and solid wastes from a residence or business and a drainfield or subsurface absorption system consisting of a series of tile or percolation lines for disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Simulation
The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Straight pipe
Delivers wastewater directly from a building, e.g., house, milking parlor, to a stream, pond, lake, or river.

Total Maximum Daily Load (TMDL)
The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Urban Runoff
Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model)
Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation. This follows the calibration of the model and ensures that the calibrated values adequately represent the watershed.

Wasteload allocation (WLA)
The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water quality standard
Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed
A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

For more definitions, see the Virginia Cooperative Extension publications available online:

Glossary of Water-Related Terms. Publication 442-758.
http://www.ext.vt.edu/pubs/bse/442-758/442-758.html

and

TMDLs (Total Maximum Daily Loads) - Terms and Definitions. Publication 442-550.
http://www.ext.vt.edu/pubs/bse/442-550/442-550.html

Appendix B: Source Assessment of Fecal Coliform

Humans and Pets

The Tye River watershed has an estimated permanent population of 16,089 (7,207 households with an average of 2.01 people per household; actual people per household varies by sub-watershed). The number of households and the number of people per household for the watershed was determined from addressable structures data supplied by the Nelson and Albemarle County GIS departments and the 2010 Census of Population and Housing for Virginia. Fecal coliform from humans can be transported to streams from failing septic systems, via straight pipes discharging directly into streams, sewage spills, or through leaky sewer lines. Although leaky sewer lines are not explicitly accounted for in modeling for this TMDL, they are considered to be part of the residential load, and should be addressed where found during implementation. Professional judgment was used to specify one pet per household for the Tye River watershed.

Failing Septic Systems

Septic system failure can result in the rise of effluent to the soil surface. Surface runoff can transport the effluent, containing fecal coliform, to receiving waters. The number of failing septic systems in each sub-watershed was determined by analyzing the ages of the structures in the watershed and applying a failure rate based on the age category. The U.S. Census (2010) provides an estimate of house ages in its summary file 3. An estimate was made for each Census block group of the fraction of houses in old (pre-1970), middle (1970-1989), and new (post-1989) age categories. This fraction was applied to the total number of houses in each block group to obtain an estimate of the number of houses in each age group in each sub-watershed. Forty percent of old houses, 20% of middle-aged houses, and 3% of new houses were assumed to have failing septic systems. In sub-watersheds 12, 13, 22 and 23 the failure rate was assumed to be higher based on stakeholder advice (50% of old houses, 30% of middle-aged houses).

Daily total fecal coliform load to the land from a failing septic system in each sub-watershed was determined by multiplying the average occupancy rate for that sub-watershed (occupancy rate of houses ranged from 1.03 to 3.3 persons per household (Census Bureau, 2010)) by the per capita fecal coliform production rate of 2.0×10^9 cfu/day (Geldreich, 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a sub-watershed with an occupancy rate of 1 person/household is 2.0×10^9 cfu/day. Transport of some portion of the fecal coliform to a stream by runoff may occur. The number of failing septic systems in the watershed is given below.

Estimated Household and Pet Population Breakdown by Sub-watershed for Tye River watershed.

Sub-watershed	Sewered Houses	People per Unsewered House	Straight Pipes	Houses with Septic Systems in each age category			Failing Septic Systems*	Pet Population
				Old	Mid-age	New		
1	0	1.83	0	9	26	11	0	6
2	0	2.24	0	14	40	18	31	169
3	0	2.01	0	25	72	32	12	70
4	0	2.04	0	88	247	111	17	86
5	24	2.11	1	12	34	16	2	16
6	307	2.02	1	10	29	13	69	337
7	0	1.77	0	8	24	11	9	46
8	0	2.22	0	1	6	2	14	72
9	0	2.32	0	32	92	41	25	129
10	48	2.13	0	64	179	81	88	446
11	34	2.12	0	28	79	36	12	87
12	92	2.04	0	12	30	13	10	360
13	0	2.09	0	12	31	14	8	43
14	0	1.88	1	34	96	44	2	9
15	0	1.84	2	7	19	10	32	165
16	0	1.87	2	8	25	11	64	372
17	0	1.80	0	41	116	52	28	177
18	0	1.22	2	6	20	9	15	147
19	0	1.53	3	24	66	29	16	57
20	0	1.08	2	19	53	24	34	175
21	0	1.03	3	30	84	38	7	38
22	0	2.13	0	26	66	30	9	46
23	4	1.97	0	62	155	70	41	209
24	0	1.85	0	22	63	28	7	37
25	0	2.11	2	21	58	27	24	122
26	0	1.59	3	9	23	11	19	98
27	0	1.42	3	5	12	6	30	155

Sub-watershed	Sewered Houses	People per Unsewered House	Straight Pipes	Houses with Septic Systems in each age category			Failing Septic Systems*	Pet Population
				Old	Mid-age	New		
28	0	2.27	0	35	36	21	34	122
29	0	2.38	0	22	68	27	80	291
30	0	2.32	0	42	147	60	22	113
31	0	2.32	0	27	71	25	21	108
32	531	2.77	2	204	211	132	9	46
33	0	2.26	0	9	33	12	5	26
34	0	2.37	0	8	27	11	22	92
35	0	2.24	0	35	104	41	23	117
36	0	2.25	1	20	61	24	48	249
37	369	1.99	0	93	84	52	26	123
38	0	2.15	0	27	77	34	128	1080
39	0	2.06	0	30	80	36	11	54
40	0	2.02	0	1	2	1	9	46
41	0	2.37	0	15	41	15	36	180
42	0	2.19	1	10	26	10	21	106
43	0	2.24	0	7	18	8	56	598
44	0	2.22	0	5	13	6	27	138
45	0	1.93	0	13	32	15	29	146
46	0	2.01	0	30	73	34	1	4
47	0	2.22	0	22	54	25	15	71
48	0	2.08	1	3	5	3	10	47
49	0	1.89	1	6	13	7	7	33
50	0	1.65	1	15	32	18	5	24
Total	**1,409**	**2.01**†	**32**	**1,308**	**3,053**	**1,405**	**1270**	**7,488**

* Failing septic systems are a subset of the septic systems presented in the previous three columns; these were determined based on house ages as described in Section 3.1.1.
† Average

Straight Pipes

Bacteria discharged from straight pipes enter the stream directly, without treatment or die-off. Straight pipe numbers and possible sub-watershed locations were estimated in consultation with stakeholders in the Tye River Watershed. Based on this criterion, it was projected that 32 houses with straight pipes exist in the Tye River watershed. The number of straight pipes in the watershed is given above.

Daily total fecal coliform load to the stream from a straight pipe in each sub-watershed was determined by multiplying the average occupancy rate for that sub-watershed by the per capita fecal coliform production rate of $3.6x10^8$ cfu/day (Geldreich, 1978). Hence, the total fecal coliform loading to the stream from a single straight pipe in a sub-watershed with an occupancy rate of 1 person/household is $2.0x10^9$ cfu/day.

Pets

The American Pet Products Manufacturers Association conducts biannual pet owner surveys in the United States. The Humane Society of the United States reports a summary of these findings: for the 2011-2012 survey: 39% of American households owned an average of 1.7 dogs, and 33% of American households owned an average of 2.2 cats (HSUS, 2012). Assuming that a unit pet is one dog or two cats, this yields (0.39*1.7 + (0.33*2.2)/2) = 1.026 unit pets per household. Therefore, the pet population in the Tye River watershed was calculated at a rate of one unit pet per permanent household. Given this assumption, there are an estimated 7207 pets in the Tye River watershed.

A dog produces fecal coliform at a rate of 4.5×10^8 cfu/day (Weiskel et al., 1996); this was assumed to be representative of a 'unit pet' – one dog or several cats. The pet population distribution among the sub-watersheds is listed above. Pet waste is generated in residential areas; surface runoff can transport bacteria in pet waste from these areas to the stream.

Cattle

Fecal coliform in cattle waste can be directly excreted to the stream, or it can be transported to the stream via surface runoff from animal waste deposited on pastures or applied to crops or pasture. There were no dairy farms in the watershed.

Distribution of Beef Cattle

The population of beef cattle in the Tye River watershed was initially estimated from the 2007 Agricultural Census. The Local Steering Committee suggested these numbers were approximately twice the actual cattle population, so the final numbers used for the TMDL were half of what was initially estimated from the 2007 Agricultural

Census. The total number of beef cows modeled throughout the year varied due to the presence or absences of calves and their weights relative to the adult cattle. The number of beef cattle and the distribution of animals among the sub-watersheds are given below for the Tye River watershed.

Beef cattle spend varying amounts of time streams, and pastures depending on the time of year. Accordingly, the proportion of fecal coliform deposited in any given land area varies throughout the year. Stream access for all beef cattle farms was estimated based on watershed visits and pasture proximity to the stream.

Beef and Dairy Cattle Populations in the Tye River watershed.

Sub-watershed	Cattle*	Sub-watershed	Cattle*	Sub-watershed	Cattle*
1	89	**24**	453	**47**	1500
2	67	**25**	327	**48**	98
3	156	**26**	0	**49**	126
4	236	**27**	0	**50**	113
5	311	**28**	87		
6	290	**29**	105		
7	121	**30**	333		
8	17	**31**	104		
9	207	**32**	423		
10	737	**33**	12		
11	522	**34**	20		
12	306	**35**	136		
13	424	**36**	146		
14	503	**37**	433		
15	301	**38**	372		
16	0	**39**	135		
17	700	**40**	0		
18	0	**41**	191		
19	79	**42**	134		
20	0	**43**	196		
21	0	**44**	119		
22	300	**45**	124		
23	795	**46**	602		
Total					12,450

* Cow-calf pairs

The following assumptions and procedures were used to estimate the distribution of cattle (and thus, fecal coliform produced by cattle) among different land use types and in streams:

a) Cattle are only confined in sub-watershed 47 as detailed in the table below. This table reflects the communications with farmers and agency personnel.
b) All other cattle are on pasture.
c) Cattle with stream access (determined as described earlier) will spend varying amounts of time in the stream during different seasons (see Table below). Cattle spend more time in the stream during the three summer months to protect their hooves from hornflies, among other reasons.
d) Thirty percent of cattle in and around streams directly deposit fecal coliform into the stream. The remaining 70% of the feces is deposited on pastures.

The resulting numbers of cattle in pastures and streams for all sub-watersheds are given in the Table below.

Time spent by cattle in confinement and in the stream.

Month	Fraction of time spent in confinement	Time spent in the stream (hours/day)
	Beef Cattle (range; typical)	
January	0%-40%; 20%	0.5
February	0%-40%; 20%	0.5
March	0%-0.7%; 0%	0.75
April	0%-0.7%; 0%	1
May	0%-0.7%; 0%	1.5
June	0%-0.7%; 0%	2.0
July	0%-0.7%; 0%	2.0
August	0%-0.7%; 0%	2.0
September	0%-0.7%; 0%	1.5
October	0%-0.7%; 0%	1
November	0%-0.7%; 0%	0.75
December	0%-40%; 20%	0.5

Distribution of the cattle population among land use types and stream.

Month	Confinement†	Pasture	Streams*
January	1,000	11,419	30
February	1,000	11,419	30
March	1,000	11,360	89
April	1,000	11,330	119
May	1,000	11,280	169
June	1,000	11,052	398
July	1,000	11,052	398
August	1,000	11,052	398
September	1,000	11,280	169
October	1,000	11,330	119
November	1,000	11,360	89
December	1,000	11,419	30

*Number of bovine equivalent defecations in the stream
†Beef cattle only confined in sub-watershed 47

Direct Manure Deposition in Streams

Direct manure loading to streams is due to beef cattle (see above) defecating in the stream. Manure loading increases during the warmer months, when cattle spend more time in water. The potential average annual manure loading directly deposited by cattle in the stream for the entire Tye River watershed, using the table above, is 2.30×10^6 lb. The associated average daily fecal coliform loading to the stream for Tye River is 8.98×10^{11} cfu. Part of the fecal coliform deposited in the stream stays suspended, while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that suspended fecal coliform bacteria are the primary form transported with the flow. Sediment-bound fecal coliform bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. Die-off of fecal coliform in the stream depends on sunlight, predation, turbidity, and other environmental factors.

Direct Manure Deposition on Pastures

Cattle that graze on pastures (see above) but do not deposit in streams contribute the majority of fecal coliform loading on pastures. Manure loading on pasture was estimated by multiplying the total number of cattle on pasture by the amount of manure produced per day. The total amount of manure produced by all types of cattle was divided by the pasture acreage to obtain manure loading (lb/ac-day) on pasture.

Fecal coliform loading (cfu/ac-day) on pasture was calculated by multiplying the manure loading (lb/ac-day) by the fecal coliform content (cfu/lb) of the manure. Because the confinement schedule of cattle changes with season: loading on pasture also changes with season.

Pasture has average annual cattle manure loadings of 11,595 lb/ac for the Tye River watershed. The associated fecal coliform loading from cattle to pasture on a daily basis averaged over the year is 4.43×10^9 cfu/ac/day for the Tye River watershed. Fecal coliform bacteria deposited on the pasture surface are subject to die-off due to desiccation and ultraviolet (UV) radiation. Runoff can transport part of the remaining fecal coliform to receiving waters.

Biosolids

There are several fields in the Tye River watershed that are permitted to receive biosolids applications. Fields associated with VPDES permit VPA01576 obtained by Synagro Central, LLC and VPDES permit VA0089729 obtained by the Nelson County Service Authority have been actively applied to since 2008. The fields associated with permit VPA01576 are in sub-watershed 3, 7, and 10; the fields associated with permit VA0089729 are in sub-watershed 17.

During the calibration and allocation periods, applications were represented in the model to all fields at application rates and permitted bacteria concentrations (2,000,000 cfu/dry g) to ensure that applications at the 'worst case' permitted limits would be allowable in the watershed. The worst case scenario application rates were 3.64 dry tons/acre for VPA01576 and 0.38 dry tons/acre for VA0089729 – the maximum rates recorded in the available records. 'Worst case' conditions were assumed, such that all available fields would be applied to each year. Based on the available records, biosolids on VPA01576 fields were applied in fall – October 7th and 17th were chosen as the application dates for sub-watershed 3, October 18th, 21st, and October 24th were chosen for sub-watershed 7, and September 19th – 22nd and October 3rd – 7th were chosen for sub-watershed 10. Based on the available records for VA0089729, the permitted fields were applied to in spring and fall – March 25th – 28th, June 3rd – 6th, and

September 4th – 9th were chosen as the application dates based on application history. This methodology represents a conservative assumption in support of the implicit margin of safety for the TMDL because most fields are not applied to each year, application rates are typically lower than those assumed for allocation scenarios, and typical bacteria concentrations in treated biosolids are much lower than 2,000,000 cfu/g.

Land Application of Solid Manure

Solid manure produced by beef cattle during confinement is collected for land application. The application of liquid and solid manure (which is discussed previous) is given in the Table below. The number of cattle, their typical weights, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given below. Solid manure is last on the priority list for application to land (it falls behind liquid manure). The amount of solid manure produced in each sub-watershed was estimated based on the populations of beef cattle in the sub-watershed (see previous Table) and their confinement schedules (see previous Table).

Schedule of cattle and poultry waste application.

Month	Solid cattle manure applied (%)*	Poultry litter applied (%)*
January	0	0
February	5	5
March	25	25
April	20	20
May	5	5
June	5	5
July	5	5
August	5	5
September	10	10
October	10	10
November	10	10
December	0	0

* As percent of annual production

Estimated solid manure production characteristics.

Type of cattle	Population	Typical weight (lb)	Solid manure produced (lb/animal-day)	Fecal coliform concentration in fresh manure (x 10^6 cfu/lb)
Beef*	12,450	1000†	60†	143§

†Source: ASAE (1998)
‡Source: MWPS (1993)
§Based on per capita fecal coliform production per day (Table 3.1) and manure production
††Based on weighted average weight assuming that 57% of the animals are older than 10 months (900 lb ea.), 28% are 1.5-10 months (400 lb ea.) and the remainder are less than 1.5 months (110 lb ea.) (MWPS, 1993)

Solid cattle manure is applied at the rate of 12 tons/ac-year to cropland and hay land, with priority given to cropland. Solid manure is applied to cropland from February through May, and October through November. Solid manure can be applied to hay land anytime of the year. The application schedule for solid manure is given in the Table above. Based on availability of land and solid manure, as well as the assumptions regarding application rates and priority of application, it was estimated that solid cattle manure was applied to 428 acres (2%) of cropland/hayland and 792 acres (3%) of pasture and pasture in the Tye River watershed.

Sheep and Goats

The sheep and goat populations (Table 3.1) were estimated from population numbers in the 2007 Agricultural Census for Amherst County and Nelson County. The populations were area-weighted according to pasture areas in each sub-watershed of Tye River. The sheep and goats were kept on pasture at all times. Sheep and goats are not usually confined and tend not to wade or defecate in the streams. Therefore, the fecal coliform produced by sheep and goats was represented as being deposited directly on pasture.

Pasture in the Tye River watershed has average annual sheep and goat manure loadings of 102 lb/ac-year. Fecal coliform loadings to the pasture in the watershed from sheep and goats on a daily basis averaged over the year are 1.4 x 10^9 cfu/ac-day.

Horses

Horse populations for the watershed were estimated from population numbers in the 2007 Agricultural Census for Amherst County and Nelson County. The populations were area-weighted according to pasture areas in each sub-watershed of Tye River. The distribution of horses among the sub-watersheds is given in the Table below. The fecal coliform originating from horses contributes to the pasture load. Fecal coliform loadings from horses on a daily basis averaged over the year and over all pastures in the watershed are 6.54×10^6 cfu/ac-day for the Tye River watershed.

Horse Population in the Tye Creek watershed.

Sub-watershed	Horse	Sub-watershed	Horse	Sub-watershed	Horse
1	2	**24**	14	**47**	18
2	3	**25**	6	**48**	5
3	6	**26**	0	**49**	9
4	9	**27**	0	**50**	5
5	12	**28**	9		
6	11	**29**	17		
7	2	**30**	20		
8	0	**31**	7		
9	4	**32**	51		
10	19	**33**	0		
11	13	**34**	1		
12	6	**35**	5		
13	8	**36**	6		
14	15	**37**	16		
15	6	**38**	11		
16	0	**39**	10		
17	21	**40**	0		
18	0	**41**	12		
19	3	**42**	9		
20	0	**43**	12		
21	0	**44**	6		
22	8	**45**	11		
23	24	**46**	18		
Total					**450**

Poultry

There is one poultry operation in the watershed. Because poultry is raised entirely in confinement, all litter produced is collected and stored prior to land application. A weighted average fecal coliform concentration was estimated for poultry litter based on relative proportions of litter from poultry type and respective fecal coliform contents. The rate of poultry litter produced in the Tye River watershed is 1.23 x 10^6 lb/year; this corresponds to a fecal coliform application rate of 2.37 x 10^{15} cfu/year. The fecal coliform bacteria produced are subject to die-off in storage and losses due to incorporation prior to being subject to transport via runoff. Poultry litter was applied at the rate of 3 tons/ac-year first to cropland and then to pastures. Poultry litter receives priority over solid cattle manure for application to agricultural areas.

Poultry litter is applied to cropland during February through May (prior to planting) and in October through November (after the crops are harvested). For spring application to cropland, poultry litter is applied on the soil surface to rotational hay and no-till corn, and is incorporated into the soil for corn in conventional tillage. In fall, poultry litter is incorporated into the soil for cropland under rye, and surface-applied to cropland under rotational hay. During June through September, poultry litter is surface-applied to pasture. The application schedule of poultry litter is given in Table 3.7. Poultry litter is not applied to cropland from September through December. Based on availability of land and poultry litter, as well as the assumptions regarding application rates and priority of application, it was estimated that poultry litter was applied to 206 acres (1%) of cropland/hayland and no pasture.

Wildlife

Wildlife fecal coliform contributions can come from excretion of waste on land and from excretion directly into streams. Information gleaned from the literature and provided by VADGIF and watershed residents was used to estimate wildlife populations. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Population numbers for each species and fecal coliform amounts were determined along with preferred habitat and habitat area.

Professional judgment was used in estimating the percent of each wildlife species depositing directly into streams, by considering each habitat area occupied (see Table below). Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among the sub-watersheds based on the area of appropriate habitat in each sub-watershed. For example, the deer population was evenly distributed across the watershed, whereas muskrat and raccoons had variable population densities based on land use and proximity to a water source. Therefore, a sub-watershed with more stream length and impoundments and more area in crop land use would have more muskrats than a sub-watershed with shorter stream length, fewer impoundments, and less area in crop land use. Distribution of wildlife among sub-watersheds is given in a Table below for the Tye River watershed.

Wildlife habitat, population density, and direct fecal deposition in streams.

Wildlife type	Habitat and Estimation Method	Population Density (animal / mi² - habitat)	Direct fecal deposition in streams (%)
Deer	Entire Watershed	30	1%
Raccoon	low density on forests not in high density area; high density on forest within 600 ft of a permanent water source or 0.5 mile of cropland; highest density in residential areas	Low density: 10 High density: 30 Highest density: 50	10%
Muskrat	16/mile of ditch or medium sized stream intersecting cropland; 8/mile of ditch or medium sized stream intersecting pasture; 10/mile of pond or lake edge; 50/mile of slow-moving river edge	-see habitat column-	25%
Beaver	300 ft buffer of main streams and impoundments on forest and pasture	10	50%
Geese	300 ft buffer around main streams and impoundments	50 – off season 70 – peak season	25%
Wood Duck	300 ft buffer around main streams and impoundments	40 – off season 60 – peak season	25%
Wild Turkey	Forest; based on kill rate per square mile of forest for Nelson county, assuming the killed birds are 10% of the total population	4	0%

Wildlife populations in the Tye River watershed.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Goose	Wood Duck	Wild Turkey
1	250	118	2	5	16	13	33
2	202	90	0	4	13	11	26
3	205	77	13	6	14	11	21
4	460	170	3	8	25	20	52
5	284	85	10	5	8	6	27
6	356	124	11	9	14	11	36
7	219	95	3	5	15	12	28
8	28	13	0	0	1	1	4
9	197	80	1	4	13	10	23
10	425	127	6	9	27	22	37
11	513	73	8	7	21	16	19
12	145	47	5	4	12	9	13
13	118	26	3	3	9	7	7
14	236	60	13	6	17	14	17
15	154	52	6	4	13	10	15
16	194	82	4	5	14	11	25
17	543	179	14	17	51	40	53
18	160	71	2	4	11	9	20
19	451	181	2	10	0	0	59
20	425	173	2	11	0	0	56
21	513	205	1	7	0	0	67
22	238	84	4	5	15	12	25
23	457	141	18	15	19	15	38
24	356	106	11	11	14	11	35
25	405	156	4	10	16	12	50
26	332	150	1	6	0	0	46
27	337	149	0	6	0	0	47
28	141	73	0	3	10	8	21
29	277	148	1	7	22	17	44
30	385	190	19	12	35	28	55
31	74	37	3	3	8	6	9
32	358	145	17	12	32	26	41
33	12	8	0	1	2	1	2

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Goose	Wood Duck	Wild Turkey
34	19	9	0	1	2	1	2
35	83	31	2	2	6	5	9
36	68	19	1	2	7	5	6
37	217	80	7	7	20	16	19
38	198	81	3	7	22	17	23
39	242	123	4	6	18	14	35
40	10	7	0	0	1	1	2
41	92	34	11	7	14	11	8
42	50	18	1	1	4	3	4
43	60	22	3	2	7	5	6
44	59	27	1	2	5	4	7
45	140	55	1	3	9	7	19
46	376	164	33	16	42	33	49
47	295	115	12	7	22	18	40
48	58	28	3	1	4	3	8
49	134	51	4	4	12	10	18
50	384	190	2	8	0	0	62
Total	**11,935**	**4569**	**275**	**300**	**662**	**522**	**1,368**

Appendix C: Model Development

Input Data Requirements

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the TMDLs for the Tye River watershed are discussed below.

Climatological Data

Hourly precipitation data were obtained from NCDC's closest National Weather Service COOP station, the Montebello Fish Hatchery in Nelson County, located 17 miles west of the watershed. Missing data were patched with data from the NCDC weather station in Bremo Bluff in Fluvanna County. Because data for some parameters needed by HSPF were not available at Montebello, data from the Tye River and the Lynchburg Airport stations were also used to complete the meteorological data set required for running HSPF.

Model Parameters

The hydrology parameters required by HSPF were defined for every land use category. Required hydrology parameters are listed in the HSPF Version 12 User's Manual (Bicknell et al., 2005). Initial estimates for required hydrology parameters were generated based on guidance in BASINS Technical Note 6 (USEPA, 2000); these parameters were refined during calibration. Each reach requires a function table (FTABLE) to describe the relationship between water depth, surface area, volume, and discharge (Bicknell et al., 2005). A visual assessment of stream characteristics for selected reaches within the Tye River watershed was completed in July 2012. Stream lengths and slopes were determined using GIS data. The procedures described in Staley et al. (2006) were used to characterize the reaches in the Tye River watershed using NRCS bankfull equations and digital elevation models. Information on the calculated stream geometry for each sub-watershed is presented in the Table below for the bankfull conditions.

Reach characteristics for Tye River.

Sub-watershed	Stream length (mile)	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
1	1.87	192	10.5	0.0001
2	4.12	71	5.8	0.0058
3	2.62	67	5.6	0.0026
4	3.11	62	5.4	0.0023
5	8.43	33	3.7	0.0205
6	6.84	36	3.9	0.0324
7	5.63	179	10.1	0.0020
8	0.95	136	8.5	0.0029
9	2.75	135	8.5	0.0026
10	4.18	133	8.5	0.0022
11	4.38	101	7.2	0.0023
12	4.84	24	3.1	0.0164
13	3.95	95	6.9	0.0031
14	3.52	46	4.5	0.0057
15	2.44	36	3.9	0.0100
16	3.63	32	2.5	0.0515
17	5.99	83	6.4	0.0049
18	4.30	29	2.3	0.0547
19	5.26	75	4.3	0.0124
20	7.20	45	3.1	0.0478
21	8.19	48	3.2	0.0409
22	3.16	84	6.4	0.0042
23	2.40	79	6.2	0.0041
24	3.68	70	5.8	0.0064
25	1.86	61	5.3	0.0119
26	5.50	55	3.5	0.0228
27	5.74	40	2.9	0.0610
28	2.76	120	8.0	0.0026
29	5.58	118	7.9	0.0014
30	2.30	114	7.7	0.0011
31	2.75	44	4.4	0.0045
32	6.76	40	4.2	0.0079
33	1.32	100	7.1	0.0001
34	1.59	29	3.4	0.0068

Sub-watershed	Stream length (mile)	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
35	1.43	27	3.3	0.0086
36	1.35	19	2.6	0.0110
37	4.35	96	7.0	0.0016
38	4.19	87	6.6	0.0018
39	6.79	34	3.7	0.0259
40	0.80	32	3.6	0.0021
41	1.38	31	3.6	0.0056
42	1.94	23	3.0	0.0077
43	1.98	18	2.5	0.0237
44	2.44	77	6.1	0.0024
45	3.99	26	3.2	0.0312
46	3.01	72	5.9	0.0032
47	1.95	61	5.3	0.0079
48	3.40	17	2.5	0.0121
49	3.43	48	4.6	0.0108
50	6.74	47	3.2	0.0701

Required water quality parameters are also given in the HSPF User's Manual (Bicknell et al., 2005). Initial estimates for bacteria loading parameters in Tye River were based on estimates of bacteria production in the watershed; estimates of die-off rates and subsurface bacteria concentrations were based on values commonly used in previous TMDLs.

Accounting for Pollutant Sources

Overview

There are currently five VPDES permitted discharge facilities (one single family domestic point source, three sewage treatment plants, and the Montebello Fish Hatchery) and one Multiple Separate Storm Sewer System (MS4) that are permitted to discharge within the Tye River watershed. During calibration and validation, reported bacteria concentrations discharged by the VPDES facilities were used as input to the model. During future conditions, loads from the facilities were modeled at their design flows and bacteria concentrations at their permitted limits (126 cfu/100 mL). The bacteria loads from the VDOT MS4 permitted area were modeled as nonpoint source, land-based loads from impervious developed areas.

Bacteria loads that are deposited by cattle, wildlife, and straight pipes directly into streams were treated as direct nonpoint sources in the model. Direct nonpoint source loadings were applied to the stream reach in each sub-watershed as appropriate. The point sources permitted to discharge bacteria in the watershed were incorporated into the simulations at the stream locations designated in their permits.

Bacteria that were deposited on land were treated as nonpoint source loadings; all or part of that load may be transported to the stream as a result of surface runoff during rainfall events. The nonpoint source loading was applied in the model in the form of fecal coliform counts to individual land use categories by sub-watershed. Bacterial die-off on the land surface and in the stream was simulated within the model. Both direct nonpoint and nonpoint source loadings were varied by month to account for seasonal differences in bacteria production and deposition characteristics, such as migratory behavior, management practices, and cattle time in streams.

The Bacteria Source Load Calculator (Zeckoski et al., 2005) was used to generate nonpoint source fecal coliform inputs to the HSPF model. This spreadsheet program takes inputs of animal numbers, land use, and management practices by sub-watershed and outputs hourly direct deposition to streams and monthly loads to each land use type. The BSLC allows direct deposition in the stream by cattle and waterfowl to occur only during daylight hours.

Modeling fecal coliform die-off

Fecal coliform die-off was modeled using first order die-off of the form:

$$C_t = C_o 10^{-kt} \qquad [4.1]$$

Where: C_t = concentration or load at time t;

C_o = starting concentration or load;

k = decay rate (day^{-1});

and t = time in days.

A review of literature provided estimates of decay rates that could be applied to waste storage and handling in the Tye River watershed (see Table below).

First order decay rates for different animal waste storage as affected by storage/application conditions and their sources.

Waste type	Storage/application	Decay rate (day^{-1})	Reference
Dairy Manure	Pile (not covered)	0.066	Crane and Moore (1986)
	Pile (covered)	0.028	
Beef manure	Anaerobic lagoon	0.375	Crane and Moore (1986)
Poultry litter	Soil surface	0.035	Giddens *et al*. (1973)
		0.342	Crane *et al*. (1980)

Based on the values cited in the literature, the following decay rates were used in simulating fecal coliform die-off in stored waste.

- Liquid dairy manure: Because the decay rate for liquid dairy manure storage could not be found in the literature, the decay rate for beef manure in anaerobic lagoons (0.375 day^{-1}) was used.
- Solid cattle manure: Based on the range of decay rates (0.028-0.066 day^{-1}) reported for solid dairy manure, a decay rate of 0.05 day^{-1} was used, assuming that a majority of manure piles are not covered.

Depending on the duration of storage, type of storage, type of manure, and die-off factor, the fraction of fecal coliform surviving in the manure at the end of storage is calculated. While calculating survival fraction at the end of the storage period, the daily addition of manure and coliform die-off of each fresh manure addition is considered to arrive at an effective survival fraction over the entire storage period. The amount of fecal coliform available for application to land per year is estimated by multiplying the survival fraction with total fecal coliform produced per year (in as-excreted manure). Monthly fecal coliform application to land is estimated by multiplying the amount of fecal coliform available for application to land per year by the fraction of manure applied to land during that month. A base-10 decay rate of 0.05 day^{-1} was assumed for fecal coliform on the land surface. The decay rate of 0.05 day^{-1} is represented in HSPF by specifying a maximum surface buildup of nine times the daily loading rate. An in-stream decay rate of 3.15 day^{-1} was used for the main stem of both Tye River and Buffalo River downstream of their headwaters. For all other tributaries and river sections an in-stream decay rate of 1.15 day^{-1} was used.

Modeling Nonpoint Sources

For modeling purposes, nonpoint fecal coliform loads were those that were deposited or applied to land, and hence, required surface runoff events for transport to streams. Fecal coliform loading by land use for all sources in each sub-watershed is presented in Chapter 3. The existing condition fecal coliform loads are based on best estimates of existing wildlife, livestock, and human populations and fecal coliform production rates. Fecal coliform in stored waste was adjusted for die-off prior to the time of land application when calculating loadings to cropland and pasture. For a given period of storage, the total amount of fecal coliform present in the stored manure was adjusted for die-off on a daily basis. The sources of fecal coliform to different land use categories and how the model handled them are briefly discussed below.

1. Cropland and Hayland: Liquid and solid manure is applied to cropland and hayland as described previously. Fecal coliform loadings to cropland were adjusted to account for die-off during storage and partial incorporation during land application. Wildlife contributions were also added to the cropland and hayland areas. For modeling, the monthly fecal coliform loading assigned to cropland was distributed over the entire cropland acreage within a sub-watershed. Thus, loading rate varied by month and sub-watershed.
2. Pasture: In addition to direct deposition from livestock and wildlife, pastures receive applications of solid manure. Applied fecal coliform loading to pasture was reduced to account for die-off during storage. For modeling, the monthly fecal coliform loading assigned to pasture was distributed over the entire pasture acreage within a sub-watershed.
3. Residential: Fecal coliform loading on rural residential land uses came from failing septic systems and waste from pets. In the model simulations, fecal coliform loads produced by failing septic systems and pets in a sub-

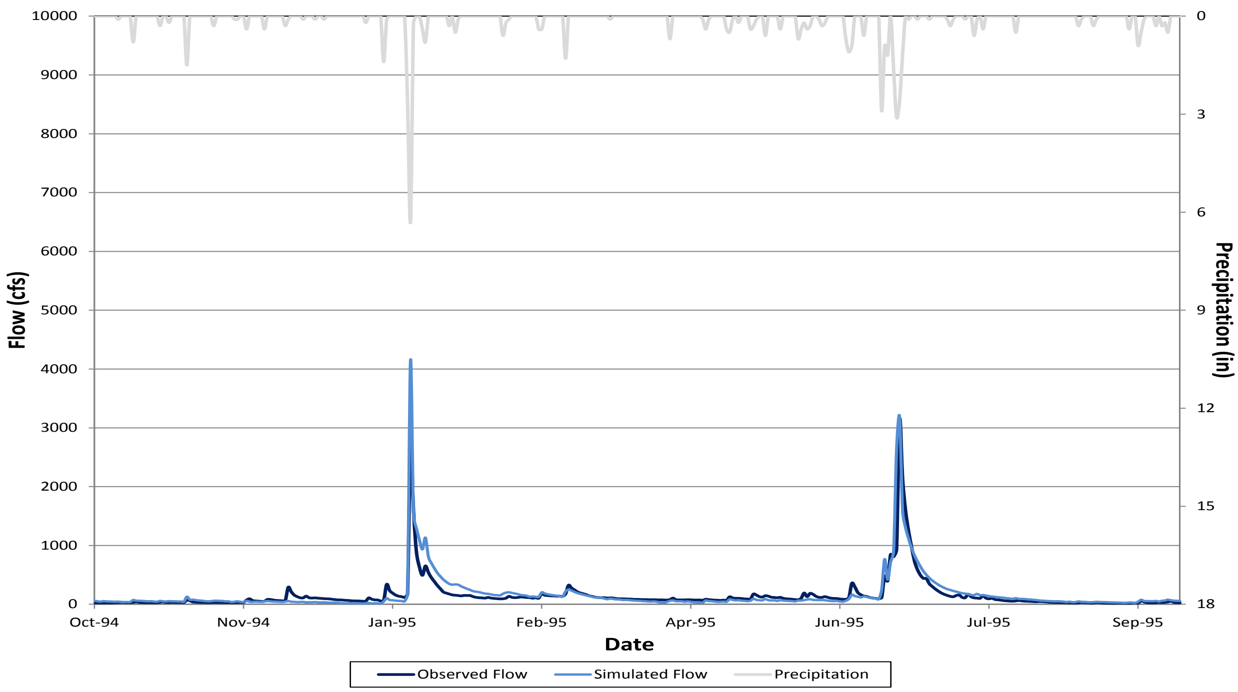
watershed were assumed to be uniformly applied to the residential pervious land use areas in each sub-watershed. Pet loads varied by sub-watershed but were constant throughout the year. Impervious areas (Table 2.2) received constant loads of 1.0 x 10^7 cfu/acre/day.

4. Forest: Wildlife not defecating in streams, cropland, or pastures provided fecal coliform loading to the forested land use. These loadings varied by month (to account for migration and hibernation) and by sub-watershed.

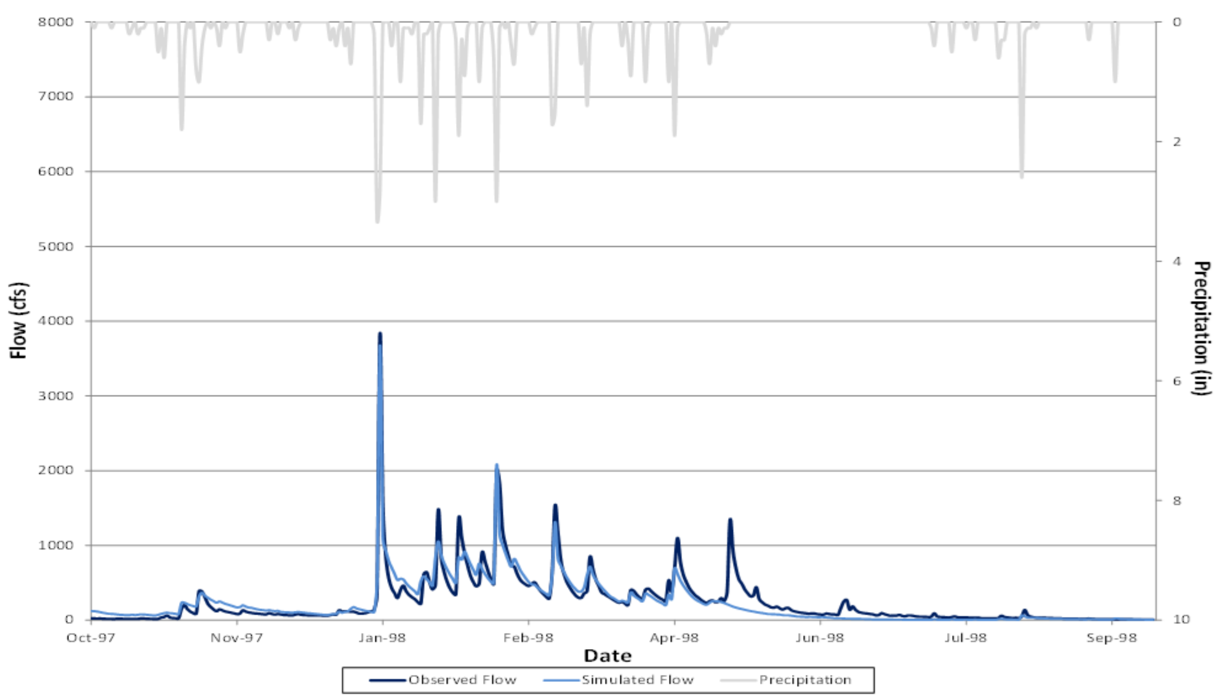
Modeling Direct Nonpoint Sources

Fecal coliform loads from direct nonpoint sources included cattle in streams, wildlife in streams, and direct loading to streams from straight pipes from residences and sewage spills. Loads from direct nonpoint sources in each sub-watershed are described in detail previously. Contributions of fecal coliform from interflow and groundwater were modeled with a constant concentration of 1.87 cfu/100mL for interflow and 1.25 cfu/100mL for groundwater for most of the watershed.

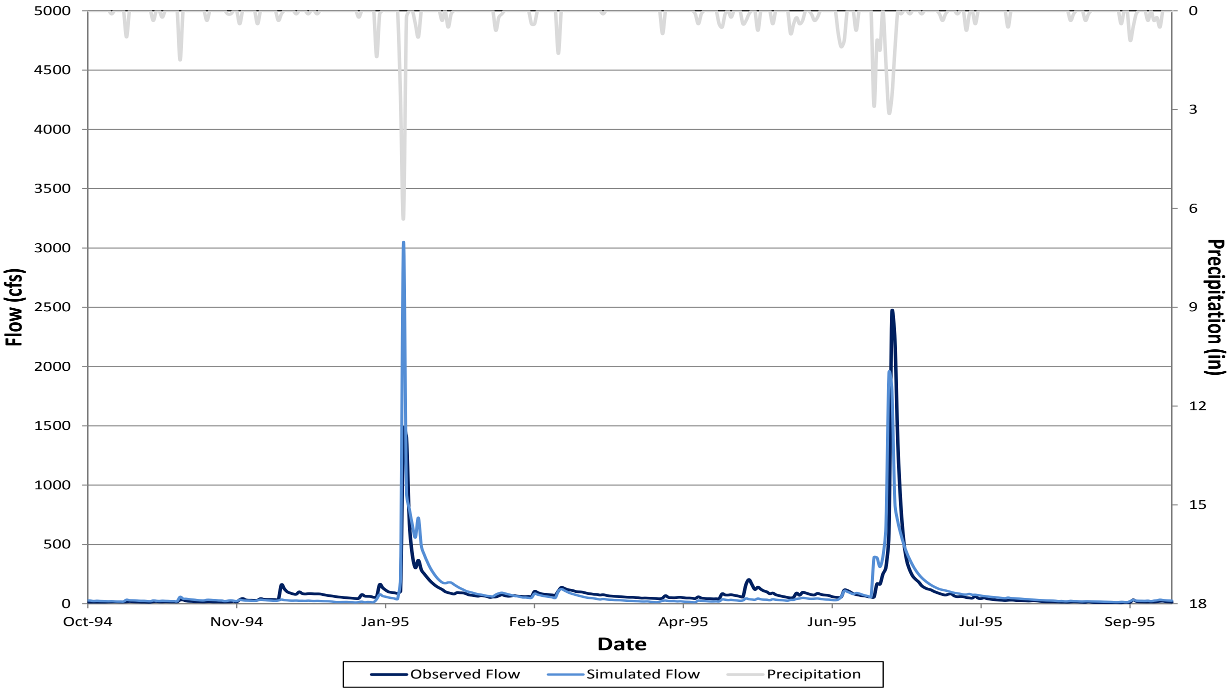
Hydrology Results: Calibration and Validation



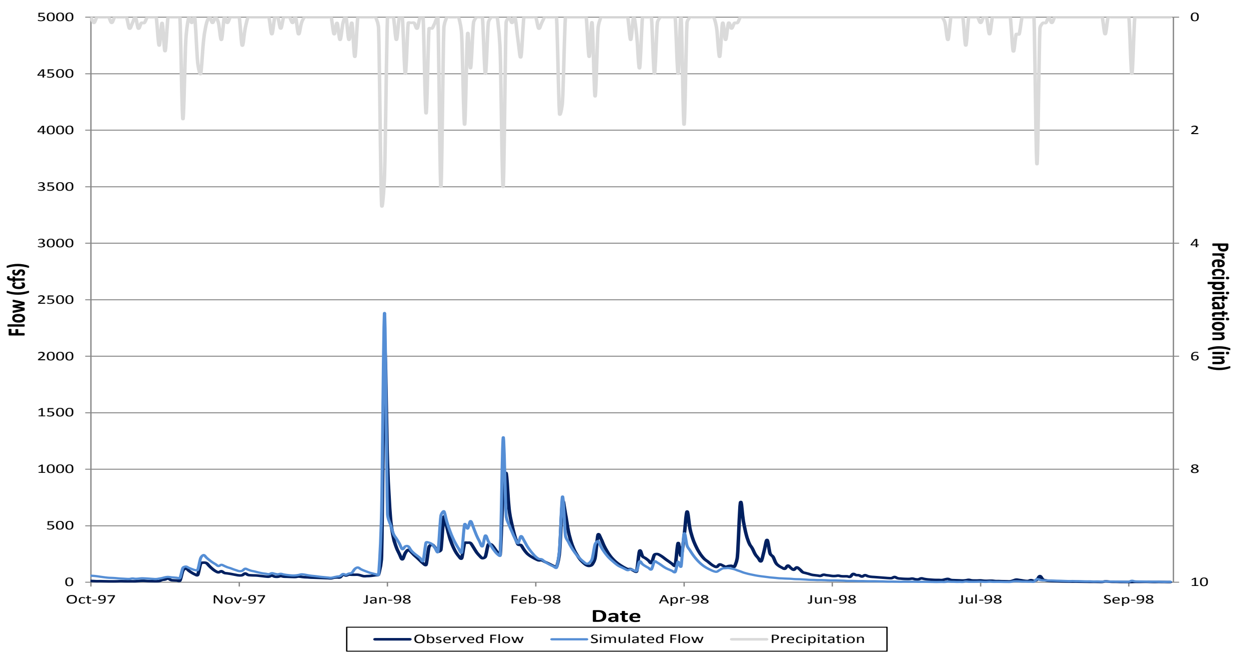
Observed and simulated flows and precipitation for a representative year in the calibration period for Tye River.



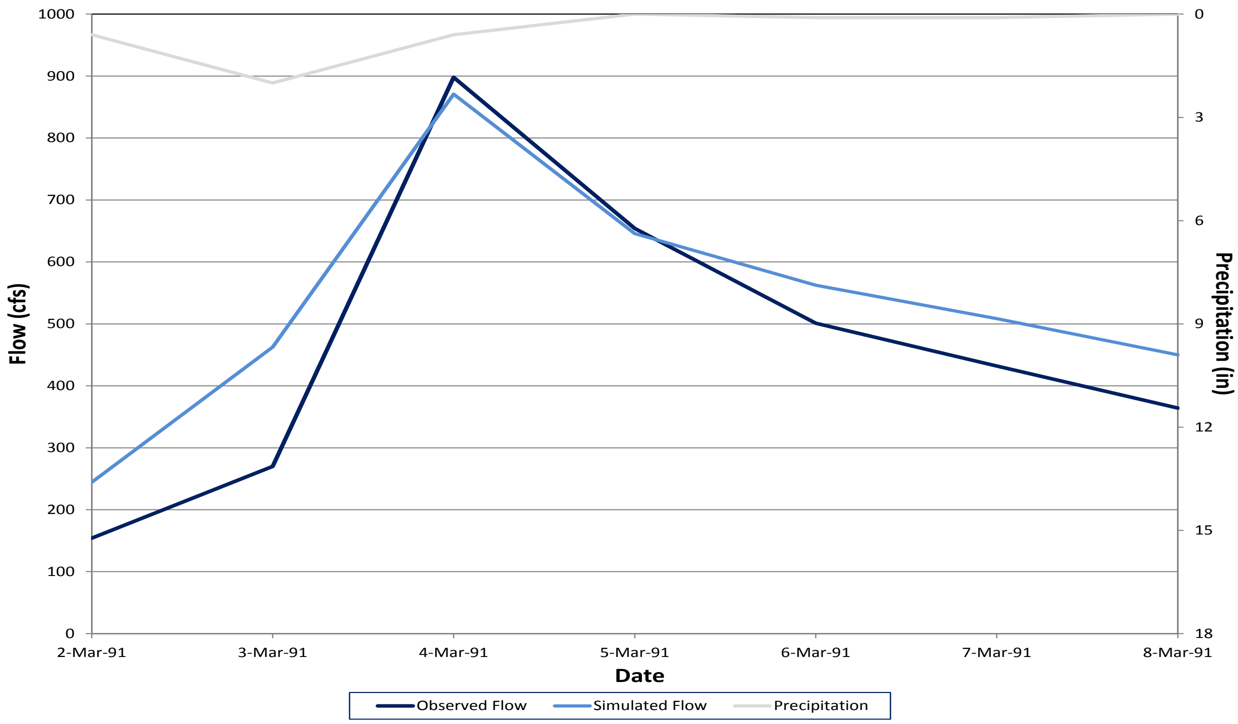
Observed and simulated flows and precipitation for Tye River during a representative year in the validation period.



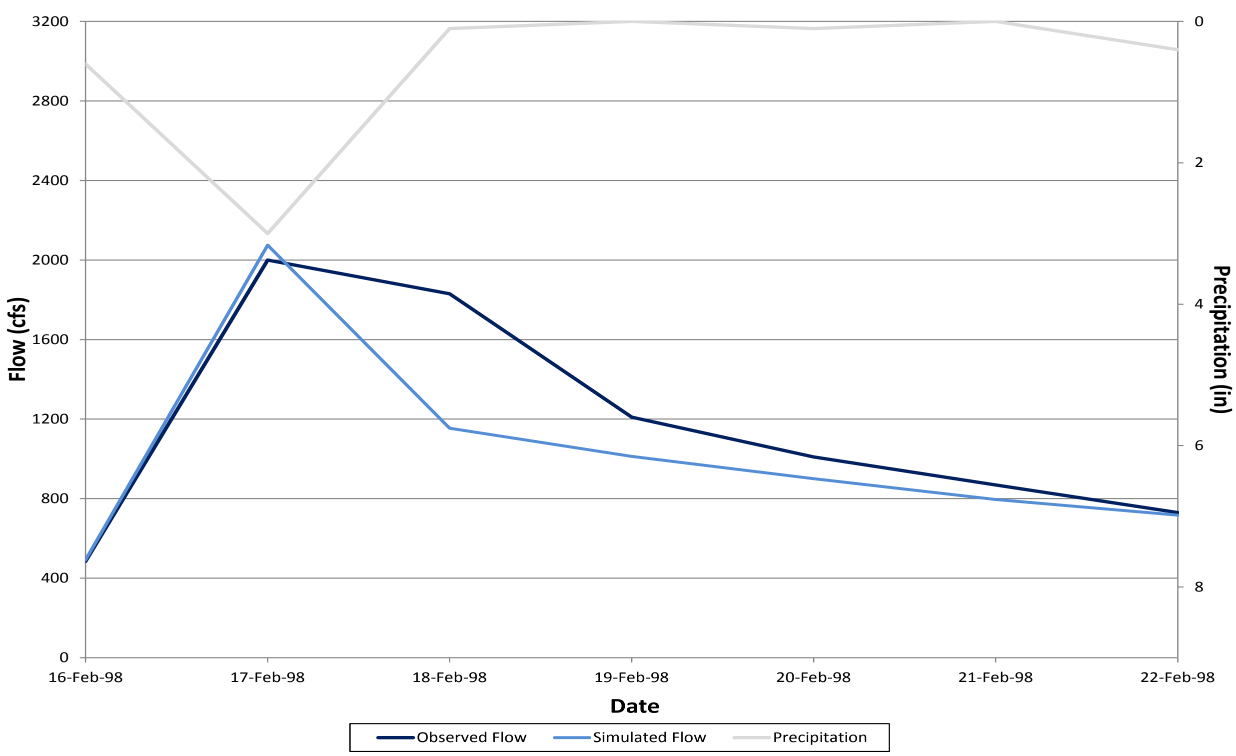
Observed and simulated flows and precipitation for a representative year in the calibration period for Tye River.



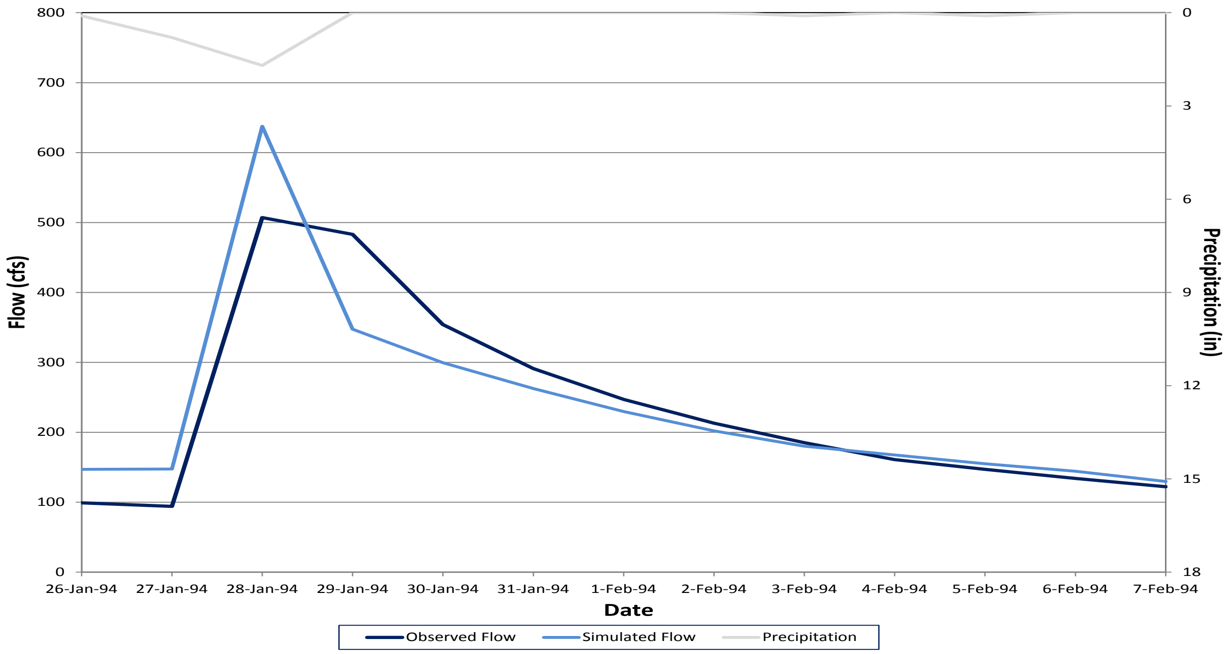
Observed and simulated flows and precipitation for Tye River during a representative year in the validation period.



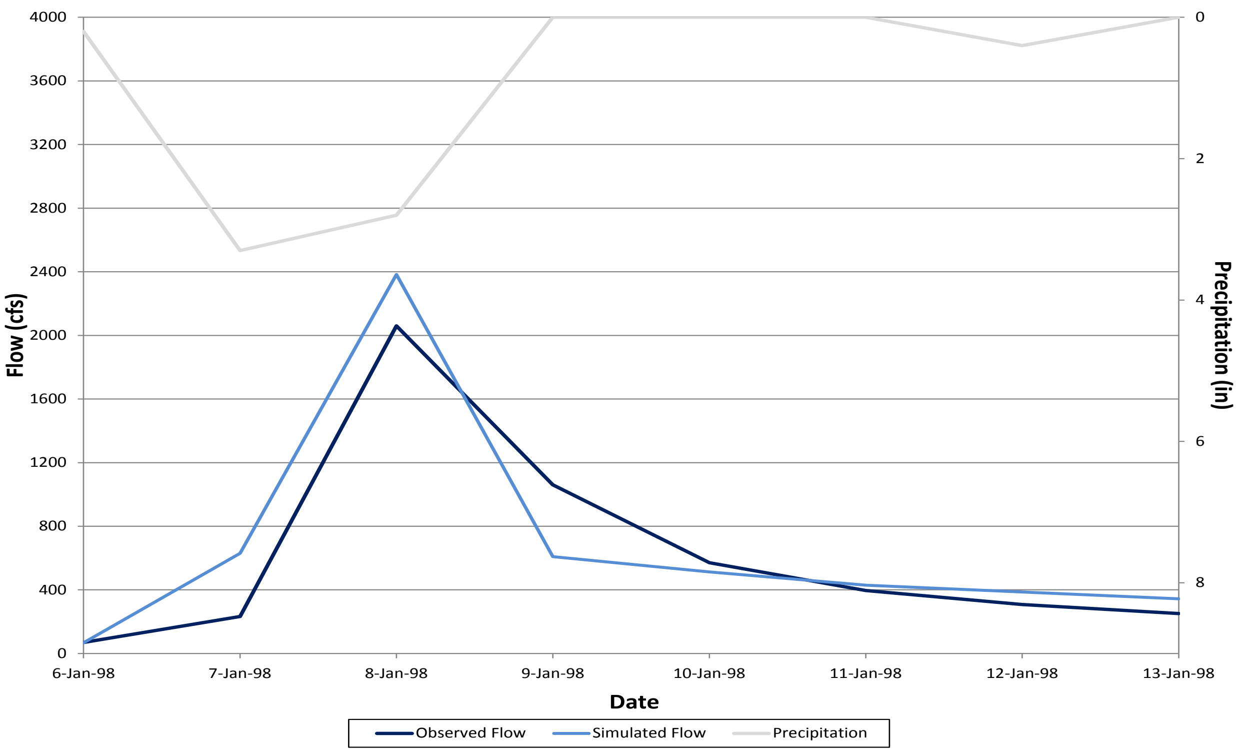
Observed and simulated flows and precipitation for Tye River for a representative storm in the calibration period.



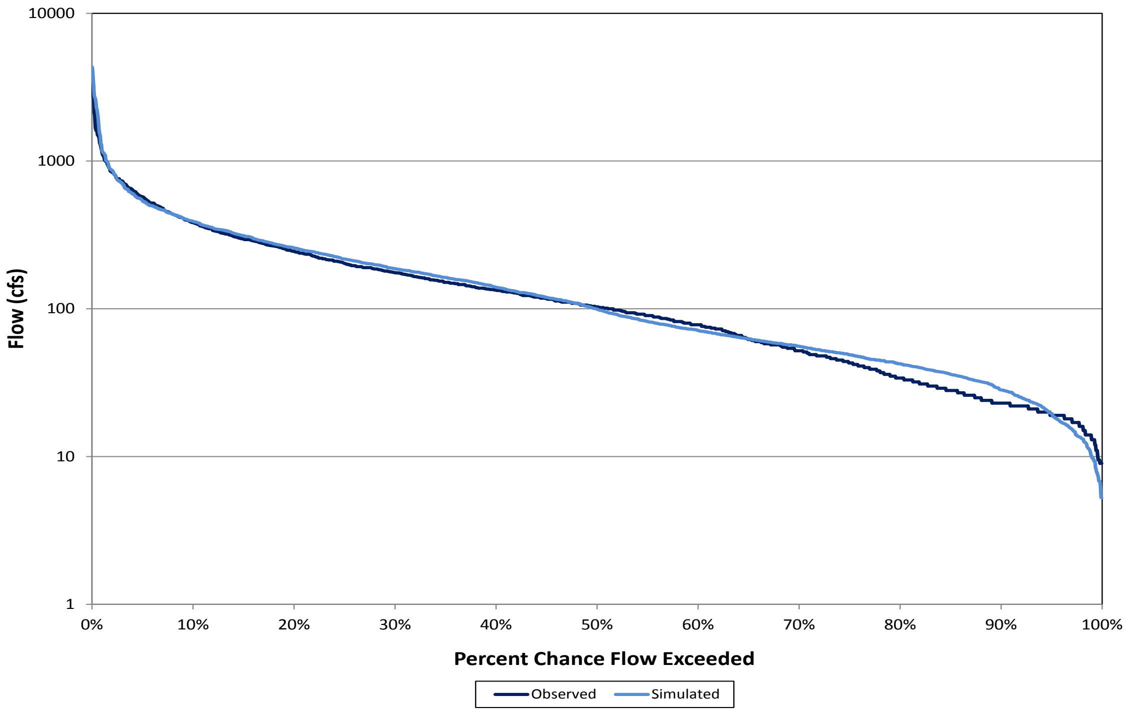
Observed and simulated flows and precipitation for Tye River for a representative storm in the validation period.



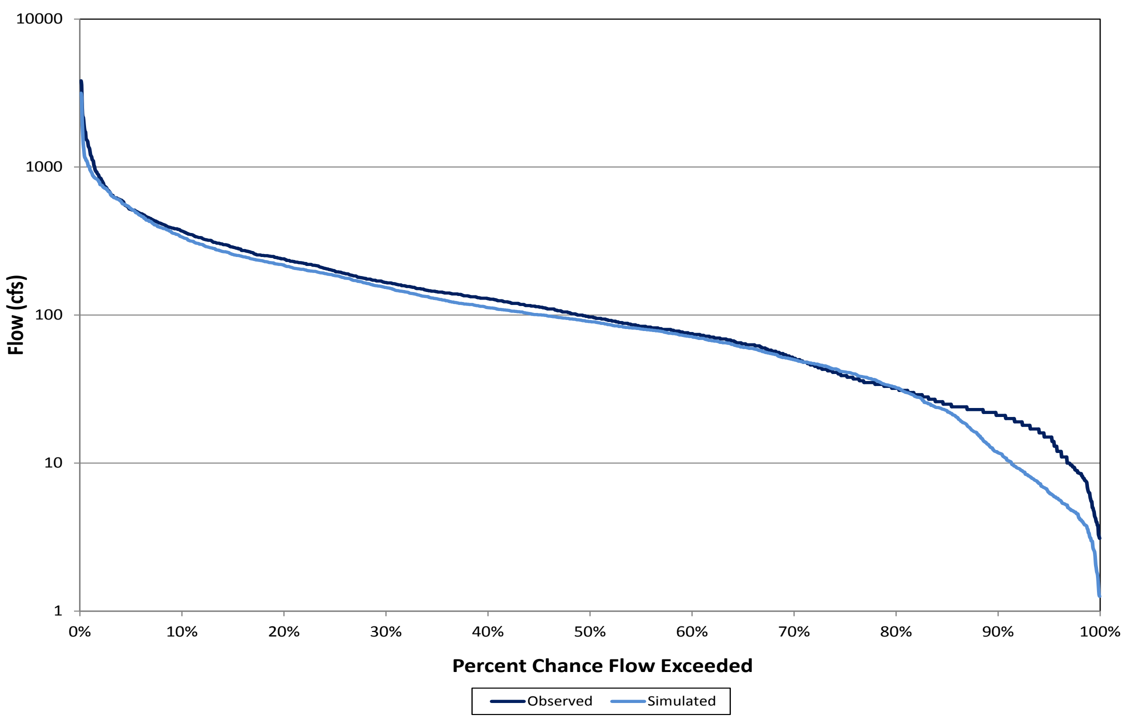
Observed and simulated flows and precipitation for Piney River for a representative storm in the calibration period.



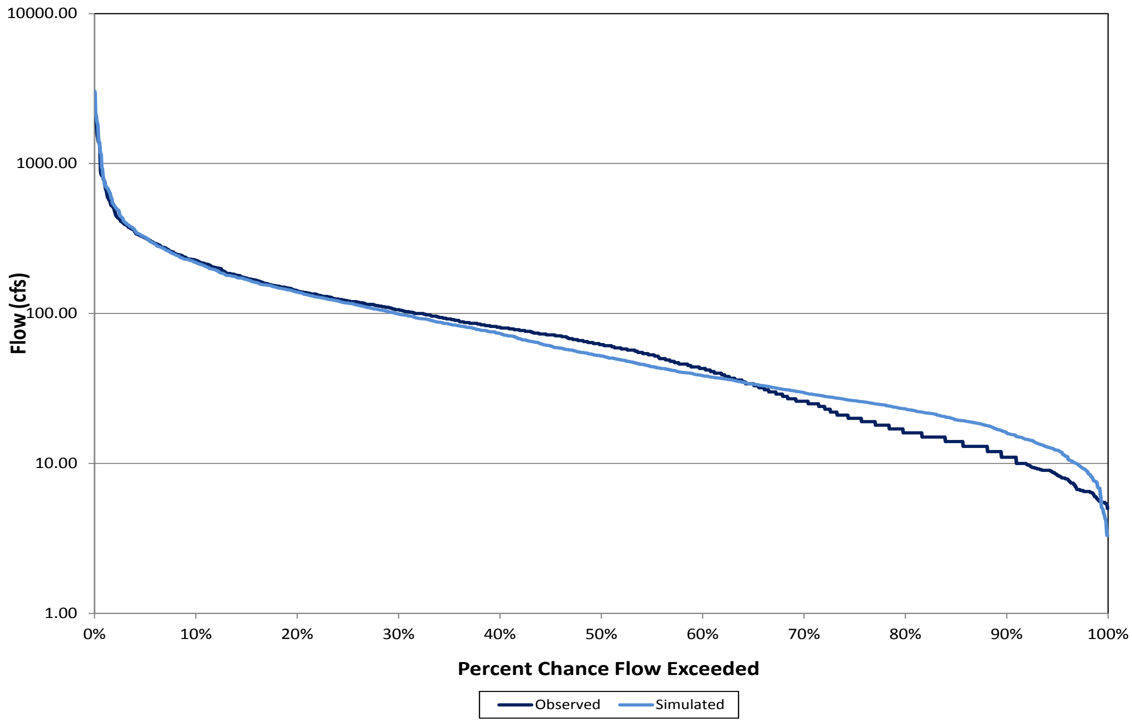
Observed and simulated flows and precipitation for Piney River for a representative storm in the validation period



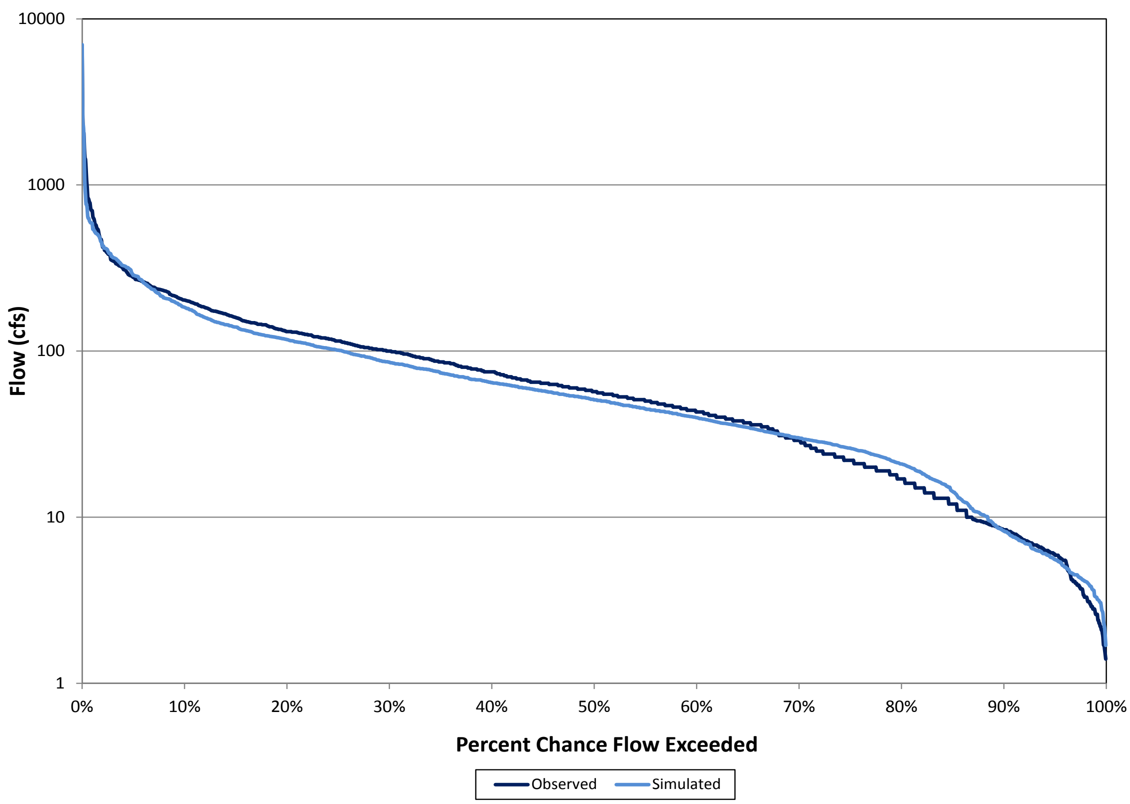
Cumulative frequency curves for the calibration period at Tye River.



Cumulative frequency curves for the validation period at Tye River.



Cumulative frequency curves for the calibration period at Piney River.



Cumulative frequency curves for the validation period for Piney River.

Flow partitioning for the hydrologic model calibration and validation is shown for Tye River and Piney River below. When the observed flow data were evaluated using Baseflow Program (Arnold, 1999), the baseflow indices for the calibration and validation periods of Tye River were 0.59 and 0.59, respectively; for Piney River they were 0.54 and 0.55, respectively. The baseflow indices for the simulated data are presented in the Tables below. The simulated baseflow indices shown match the observed values well. The final calibrated hydrology parameters are also shown in Tables below.

Table 4.9. Flow partitioning for the calibration and validation periods for Tye River.

Average Annual Flow	Calibration	Validation
Total Runoff (in)	26.805	23.227
Total Surface Runoff (in)	3.372 (13%)	2.42 (10%)
Total Interflow (in)	7.699 (29%)	7.044 (30%)
Total Baseflow (in)	15.734 (59%)	13.763 (59%)
Baseflow Index	0.59	0.59

Table 4.10. Flow partitioning for the calibration and validation periods for Piney River.

Average Annual Flow	Calibration	Validation
Total Runoff (in)	29.637	25.788
Total Surface Runoff (in)	4.545 (15%)	3.167 (10%)
Total Interflow (in)	11.135 (38%)	10.205 (30%)
Total Baseflow (in)	13.957 (47%)	12.416 (48%)
Baseflow Index	0.54	0.55

Hydrology parameters for Tye River.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…
PERLND				
PWAT-PARM2				
FOREST	Fraction forest cover	none	1.0 forest, 0.0 other	Forest cover
LZSN	Lower zone nominal soil moisture storage	inches	10.5	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.016(pond)-0.140[a]	Soil and cover conditions
LSUR	Length of overland flow	feet	28-856	Topography
SLSUR	Slope of overland flow plane	none	0.0204-0.4571	Topography
KVARY	Groundwater recession variable	1/in	0.0	Calibrate
AGWRC	Base groundwater recession	none	0.96-0.965	Calibrate
PWAT-PARM3				
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	Soil properties
DEEPFR	Fraction of GW inflow to deep recharge	none	0.01	Geology
BASETP	Fraction of remaining ET from baseflow	none	0.02	Riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0.0	Marsh/wetlands ET
PWAT-PARM4				
CEPSC	Interception storage capacity	inches	monthly[b]	Vegetation
UZSN	Upper zone nominal soil moisture storage	inches	monthly[b]	Soil properties
NSUR	Mannings' n (roughness)	none	0.35 forest; 0.30 cropland and hayland; 0.20 pasture; 0.10 residential and water	Land use, surface condition
INTFW	Interflow/surface runoff partition parameter	none	3.0	Soils, topography, land use
IRC	Interflow recession parameter	none	0.81	Soils, topography, land use
LZETP	Lower zone ET parameter	none	monthly[b]	Vegetation

Hydrology parameters for Tye River.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…
IMPLND				
IWAT-PARM2				
LSUR	Length of overland flow	feet	150	Topography
SLSUR	Slope of overland flow plane	none	0.140	Topography
NSUR	Mannings' n (roughness)	none	0.1	Land use, surface condition
RETSC	Retention/interception storage capacity	inches	0.070	Land use, surface condition
IWAT-PARM3				
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation
RCHRES				
HYDR-PARM2				
KS	Weighting factor for hydraulic routing		0.5	

[a]Varies with land use (available on request)

[b]Varies by month and with land use

Hydrology parameters for Piney River.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF...
PERLND				
PWAT-PARM2				
FOREST	Fraction forest cover	none	1.0 forest, 0.0 other	Forest cover
LZSN	Lower zone nominal soil moisture storage	inches	6.5	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.09(pond)-0.078[a]	Soil and cover conditions
LSUR	Length of overland flow	feet	28-856	Topography
SLSUR	Slope of overland flow plane	none	0.0204-0.4571	Topography
KVARY	Groundwater recession variable	1/in	0.0	Calibrate
AGWRC	Base groundwater recession	none	0.96-0.965	Calibrate
PWAT-PARM3				
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	Soil properties
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BASETP	Fraction of remaining ET from baseflow	none	0.0	Riparian vegetation
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PWAT-PARM4				
CEPSC	Interception storage capacity	inches	monthly[b]	Vegetation
UZSN	Upper zone nominal soil moisture storage	inches	monthly[b]	Soil properties
NSUR	Mannings' n (roughness)	none	0.35 forest; 0.30 cropland and hayland; 0.20 pasture; 0.10 residential and water	Land use, surface condition
INTFW	Interflow/surface runoff partition parameter	none	3.0	Soils, topography, land use
IRC	Interflow recession parameter	none	0.81	Soils, topography, land use
LZETP	Lower zone ET parameter	none	monthly[b]	Vegetation

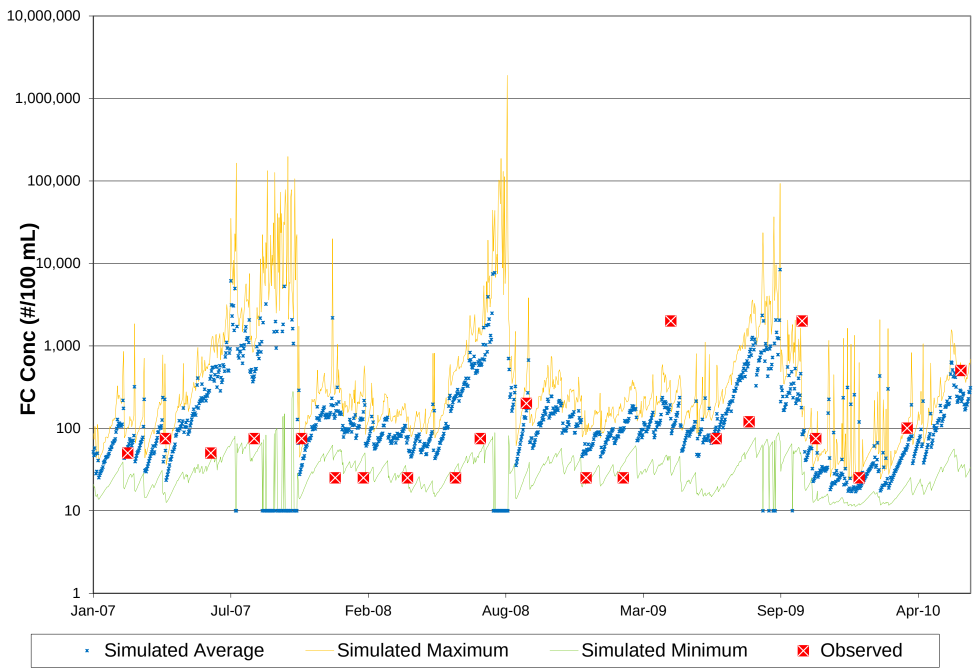
Hydrology parameters for Piney River.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF...
IMPLND				
IWAT-PARM2				
LSUR	Length of overland flow	feet	150	Topography
SLSUR	Slope of overland flow plane	none	0.140	Topography
NSUR	Mannings' n (roughness)	none	0.1	Land use, surface condition
RETSC	Retention/interception storage capacity	inches	0.070	Land use, surface condition
IWAT-PARM3				
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation
RCHRES				
HYDR-PARM2				
KS	Weighting factor for hydraulic routing		0.5	

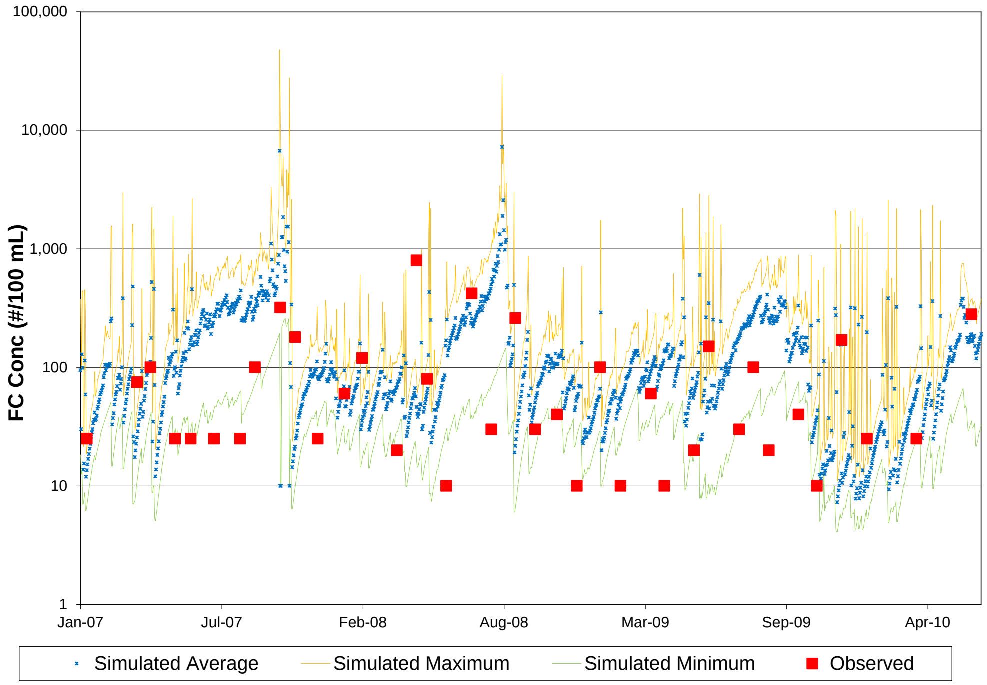
[a]Varies with land use (available on request)

[b]Varies by month and with land use

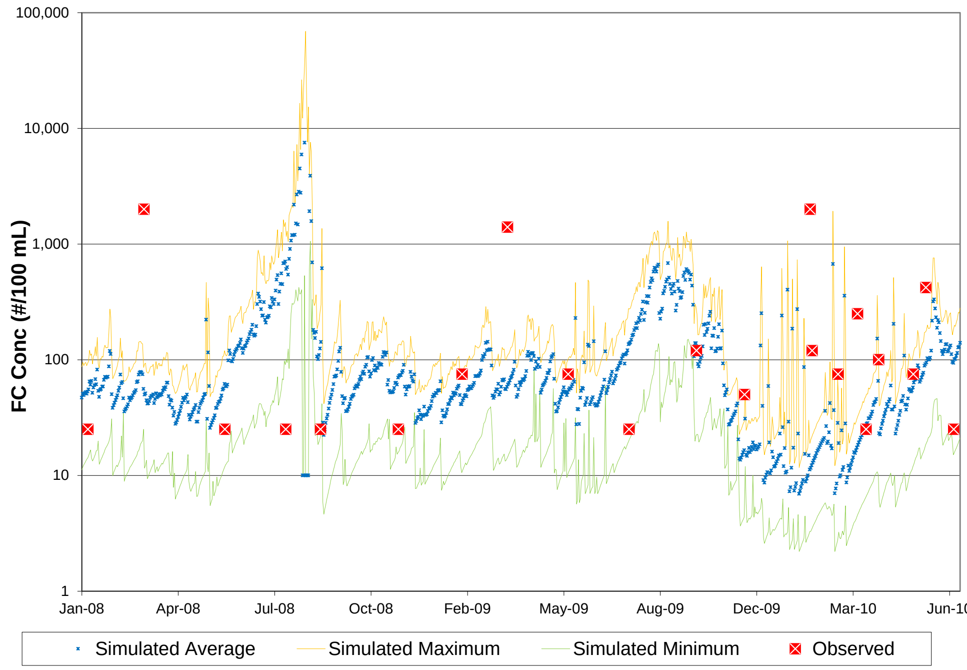
Bacteria Results: Calibration



Observed *E. coli* data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Tye River (2-TYE020.67) for the calibration period (January 1, 2007 to June 30, 2010).

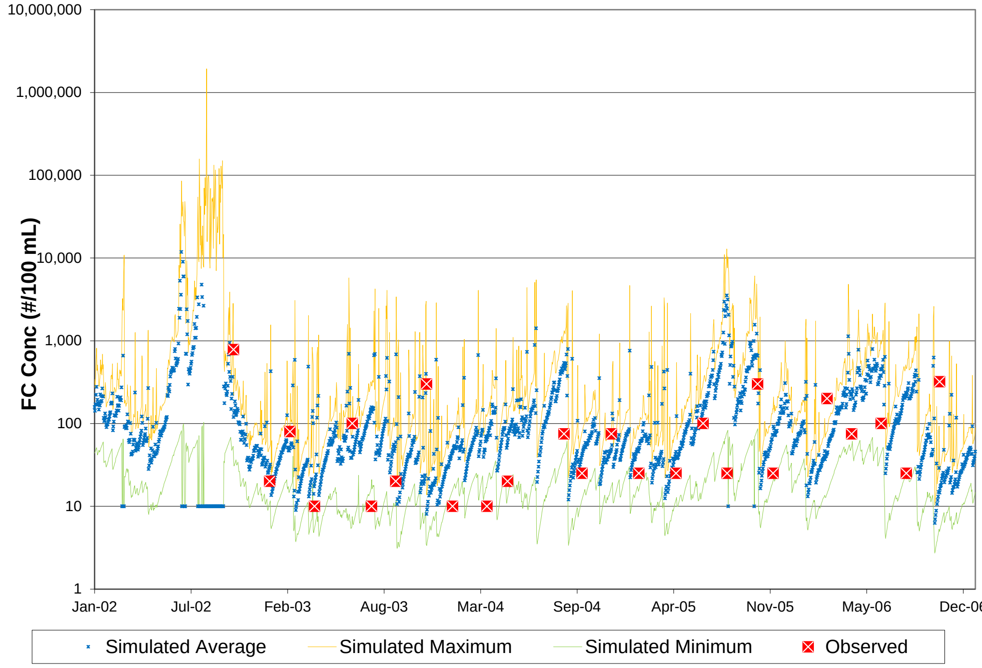


Observed *E. coli* data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Piney River (2-PYN005.29) for the calibration period (January 1, 2007 to June 30, 2010).

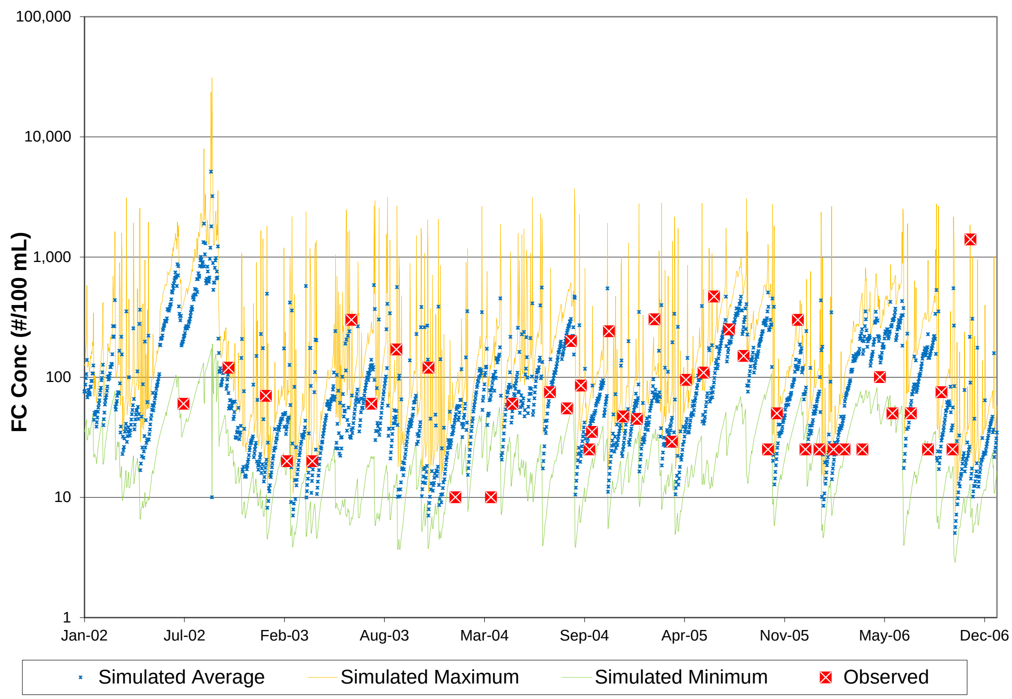


Observed *E. coli* data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Buffalo River (2-BUF002.10) for the calibration period (January 1, 2008 to June 30, 2010).

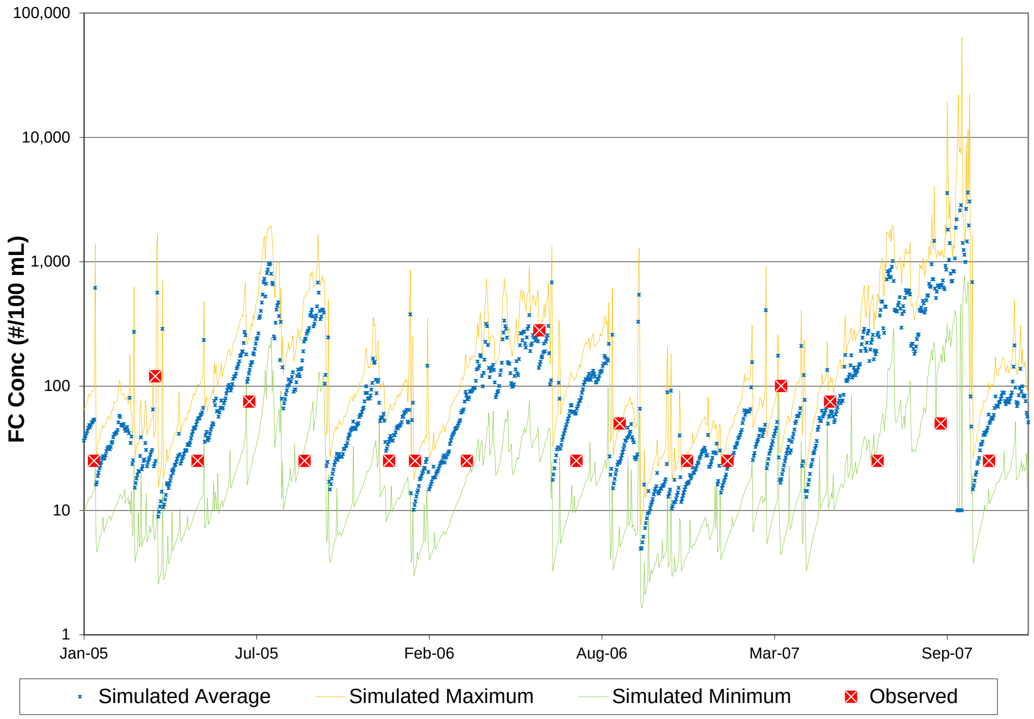
Validation



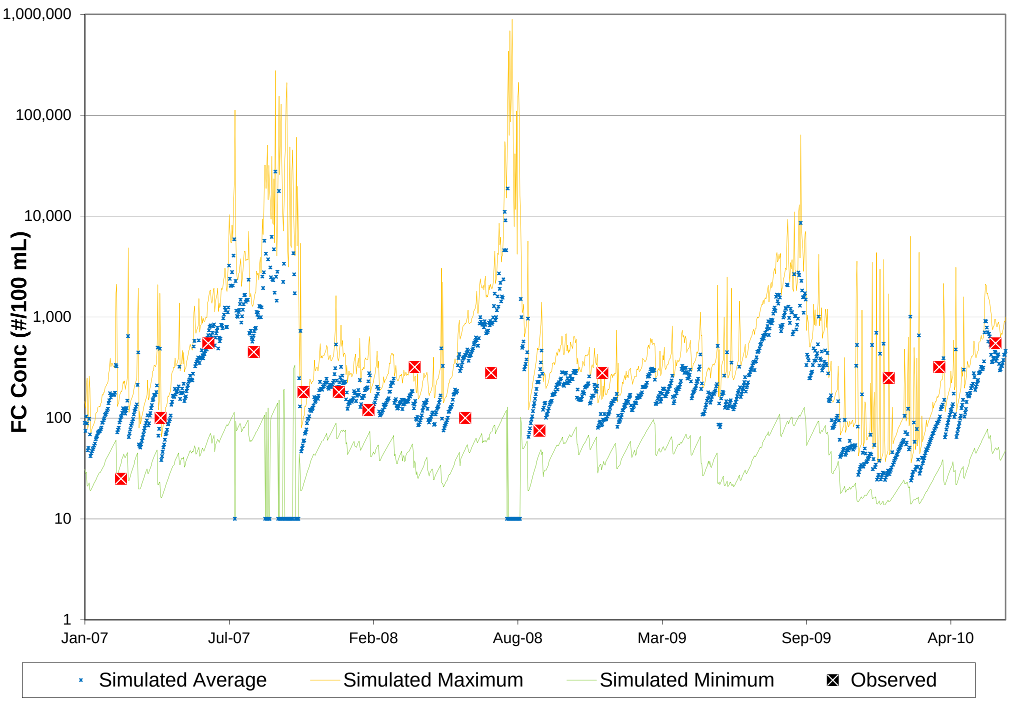
Observed *E. coli* data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Tye River (2-TYE020.67) for the validation period (January 1, 2002 to December 31, 2006).



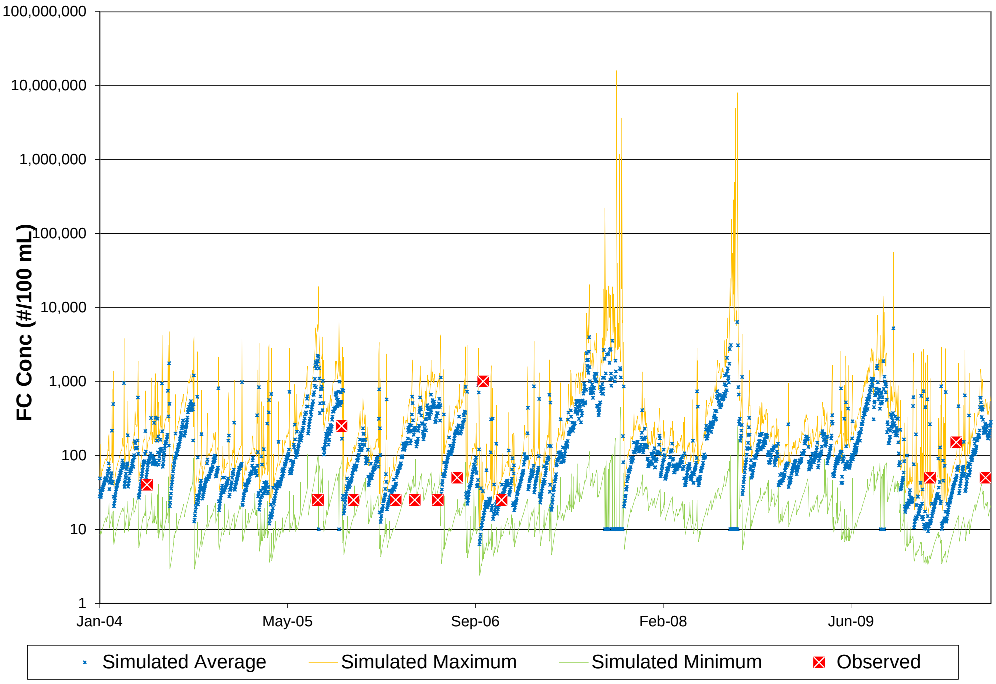
Observed *E. coli* data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Piney River (2-PYN005.29) for the validation period (January 1, 2002 to December 31, 2006).



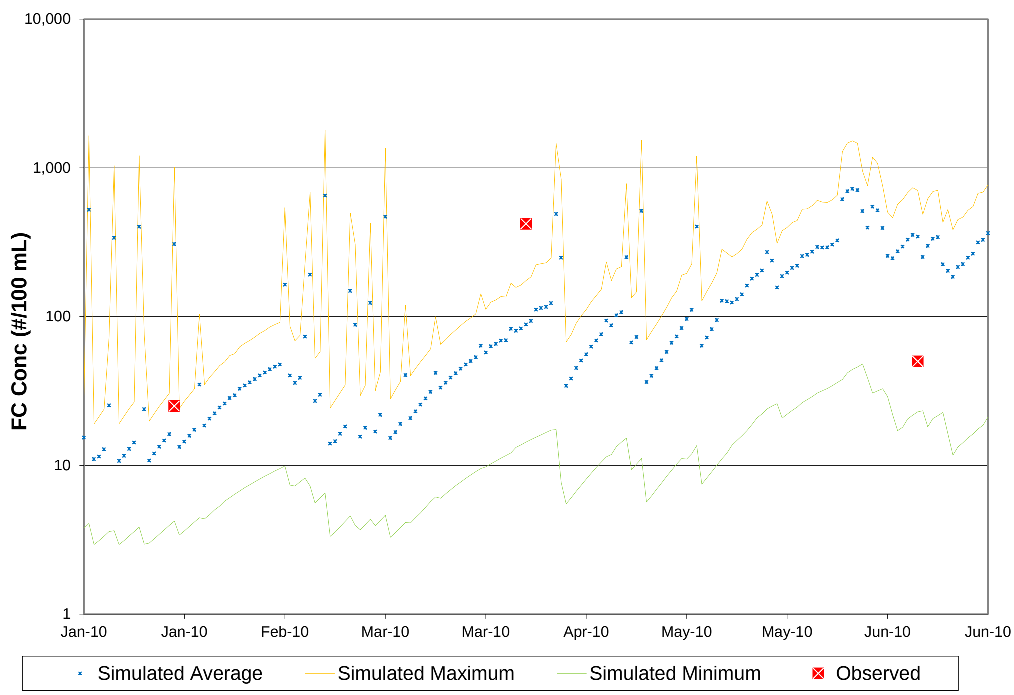
Observed *E. coli* data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Buffalo River (2-BUF002.10) for the validation period (January 1, 2005 to December 31, 2006).



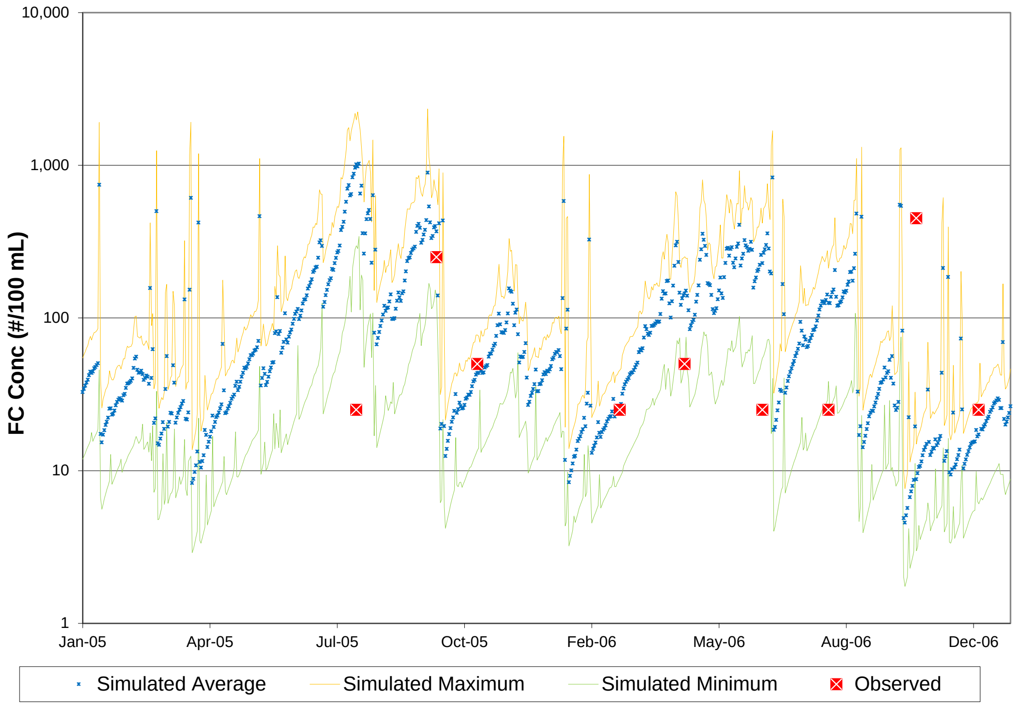
Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Hat Creek (2-HAT000.14) for the validation period (January 1, 2007 through June 30, 2010).



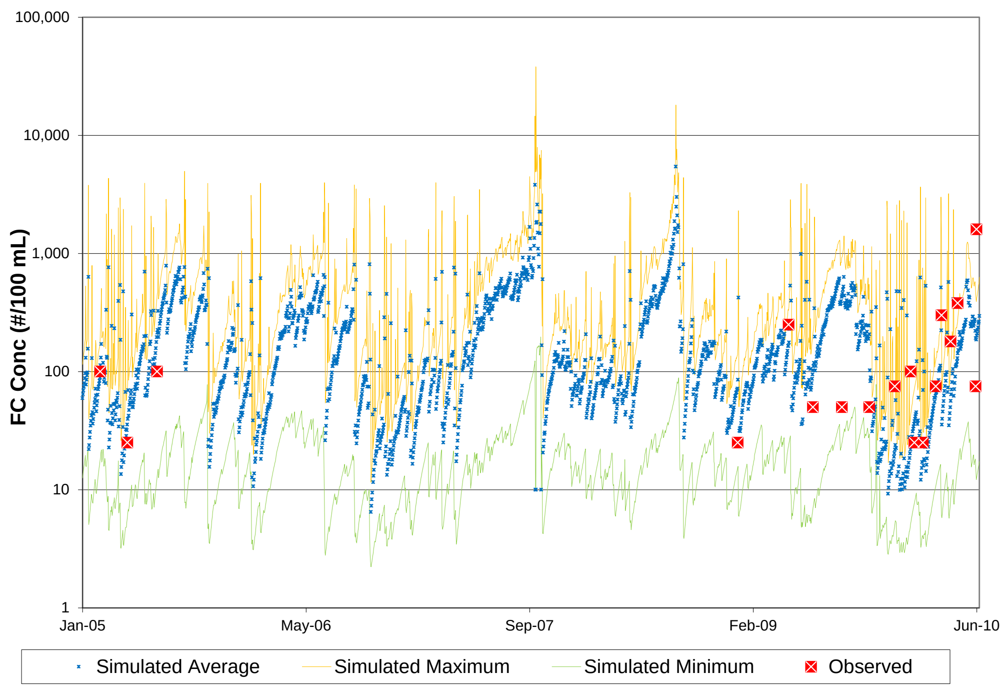
Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Tye River (2-TYE008.77) for the validation period (January 1, 2004 through June 30, 2010).



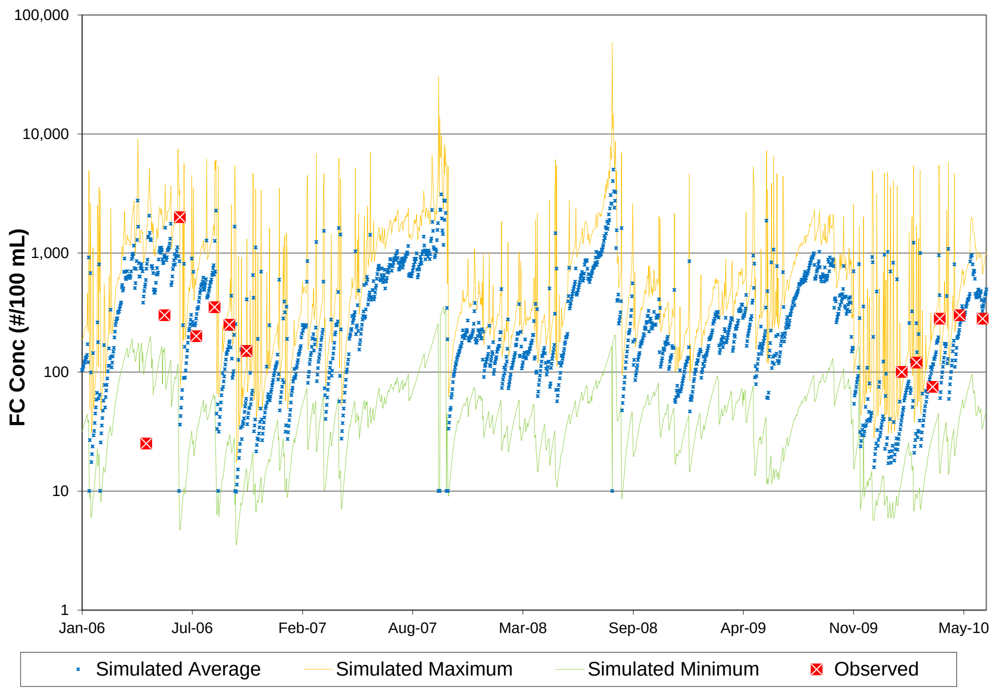
Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Rucker Run (2-RKR000.20) for the validation period (January 1, 2010 through June 30, 2010).



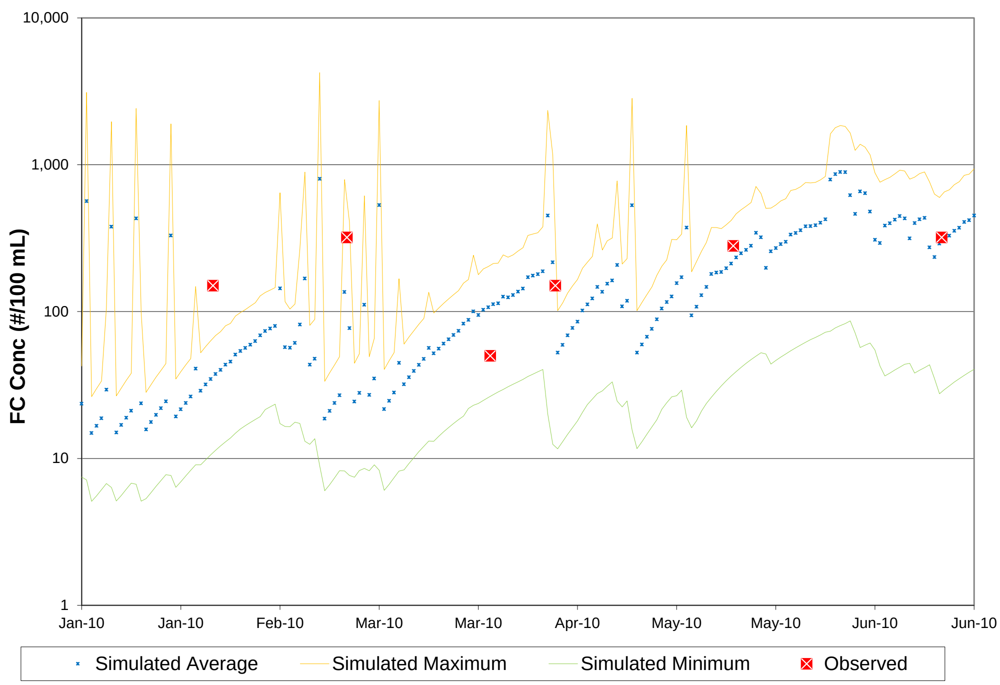
Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Tye River (2-TYE000.30) for the validation period (Janauary 1, 2005 through December 31, 2006).



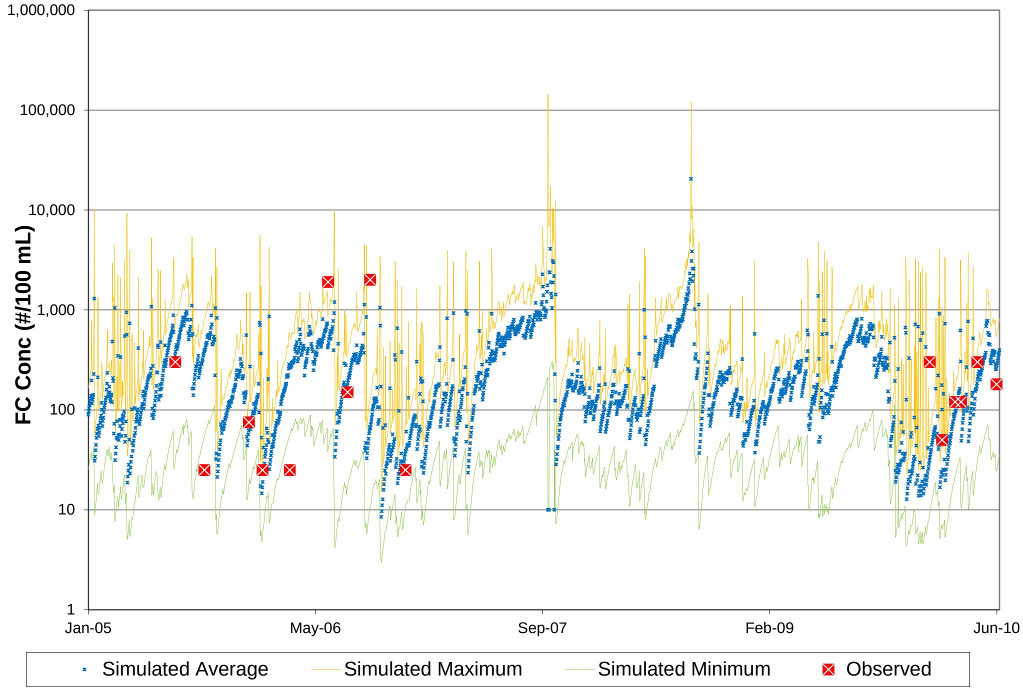
Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Buffalo River (2-BUF023.21) for the validation period (July 1, 2005 through June 30, 2010).



Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Mill Creek (2-MIN002.25) for the validation period (January 1, 2006 through June 30, 2010).



Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Rutledge Creek (2-RTD003.08) for the validation period (January 1, 2010 through June 30, 2010).



Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Turner Creek (2-TNR00.25) for the validation period (January 1, 2005 through June 30, 2010).

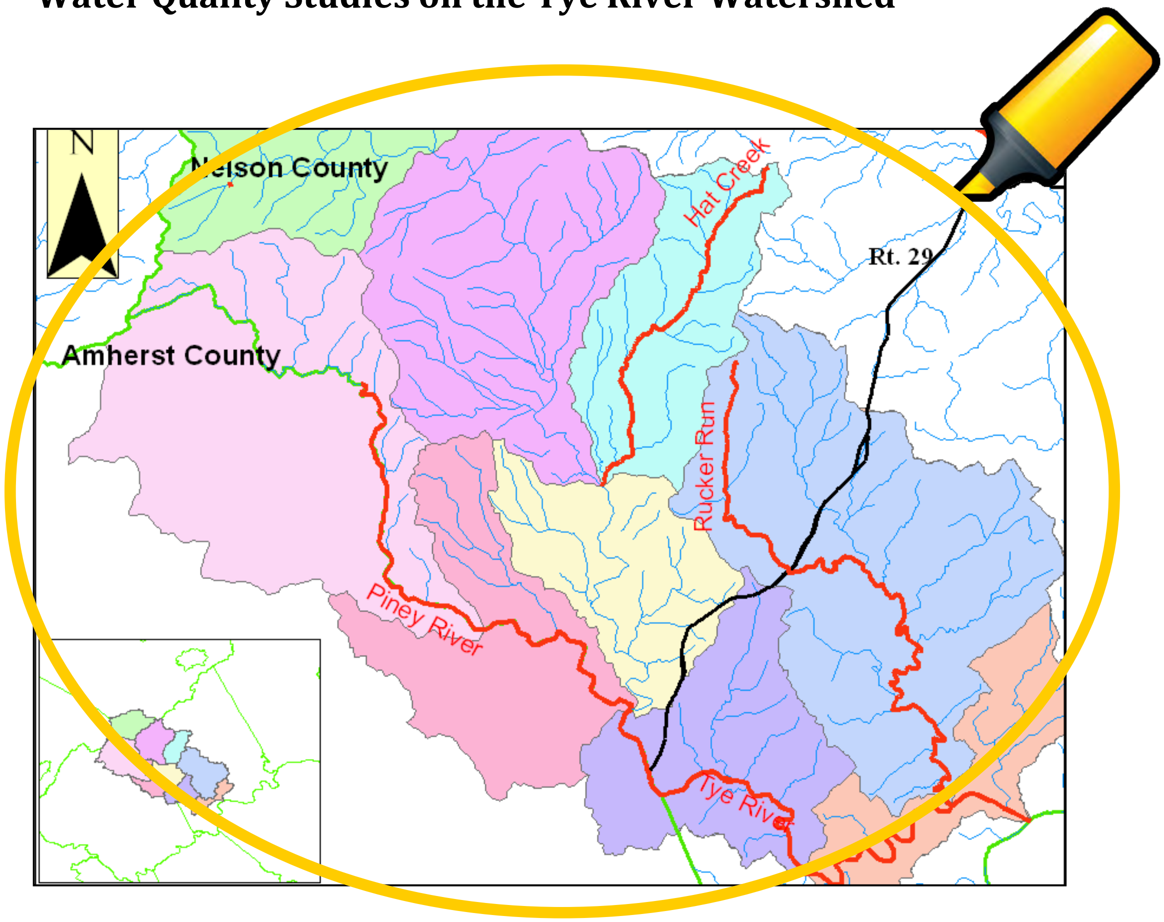
Calibrated bacteria water quality parameters for the Tye River watershed.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…
PQUAL				
SQO	Initial storage of constituent	#/ac	0	Land use
POTFW	Washoff potency factor	#/ton	0	
POTFS	Scour potency factor	#/ton	0	
ACQOP	Rate of accumulation of constituent	#/day	Monthly[a]	Land use
SQOLIM	Maximum accumulation of constituent	#	9 x ACQOP[a]	Land use
WSQOP	Wash-off rate	in/hr	2.0	Land use
IOQC	Constituent conc. in interflow	$\#/ft^3$	531	
AOQC	Constituent conc. in active groundwater	$\#/ft^3$	354	
IQUAL				
SQO	Initial storage of constituent	#/ac	$1x10^7$	
POTFW	Washoff potency factor	#/ton	0	
ACQOP	Rate of accumulation of constituent	#/day	$1x10^7$	Land use
SQOLIM	Maximum accumulation of constituent	#	$3x10^7$	Land use
WSQOP	Wash-off rate	in/hr	2.0	Land use
GQUAL				
FSTDEC	First order decay rate of the constituent	1/day	1.15 for tributaries; 3.15 for mainstream	
THFST	Temperature correction coeff. for FSTDEC		1.05	

[a]Values varied by month and with land use (available on request

HIGHLIGHTING LOCAL STREAMS:

Water Quality Studies on the Tye River Watershed



The Virginia Department of Environmental Quality (VADEQ) monitors the Commonwealth's streams and rivers (*there are* ***52,232 miles*** *of them!*) for five uses: fishing, swimming, wildlife, aquatic life (benthic), and drinking. When streams fail to meet standards based on these uses, they are declared to be "impaired", or not fully supportive of their beneficial uses, and placed on Virginia's impaired waters list. VADEQ reports this list to the USEPA every other year as required by the federal **Clean Water Act** of 1972. Based on routine water quality monitoring, several streams in Nelson County have been added to the list of waterways in Virginia that do not meet water quality standards. Hat Creek, Piney River, Rucker Run and the Tye River were listed as "impaired" in 2004, 2006, and 2008 due to violations of the recreational use standard (excess *e. Coli* bacteria). A **Total Maximum Daily Load** must be prepared for streams that do not meet water quality standards and are listed as impaired.

Are we being singled out?
No. In Virginia, 68% of assessed streams are considered "impaired".

Total Maximum Daily Load

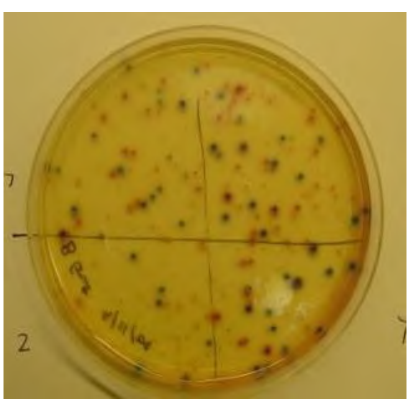
A TMDL is a pollution budget for a stream, which sets a maximum amount of a pollutant that can enter a stream but still allow the stream to maintain water quality standards. It is also the process of improvement that Virginia uses to make streams healthier and cleaner. This report is part of the TMDL studies for these streams.

What is the primary contact standard?

The code of Virginia states that all of Virginia's waterways are designated for several different uses, including "recreation… e.g. swimming and boating" (9VAC 25-260-10). These activities involve contact with the water – people getting their feet, bodies, and heads wet. People are naturally attracted to waterbodies whether to wade, fish, swim or paddle, and streams should be **safe** places to enjoy Virginia's great outdoors.

Why do we care about bacteria? Why is too much bacteria a problem?

VADEQ is charged with ensuring that Virginia's waterways are **safe** places to play and swim. This implies a low risk of contracting a gastro-intestinal illness from being in the water. Illnesses of this type can be caused by bacteria in the stream water. VADEQ monitors a strain of bacteria in the fecal coliform family to ensure that streams are **safe** for people to enjoy. This strain is known as *Escherichia coli* or *E. coli*. VADEQ visits streams all over the Commonwealth on a regular basis to take water samples and measure the concentration of bacteria colonies. The higher the concentration of bacteria in the water, the higher the likelihood of ingesting *E. coli*, and the greater the risk of illness. Virginia's water quality standard is set so that a stream's samples should not exceed an *E. coli* concentration of 235 colonies per 100 mL of stream water more than 10.5% of the time.

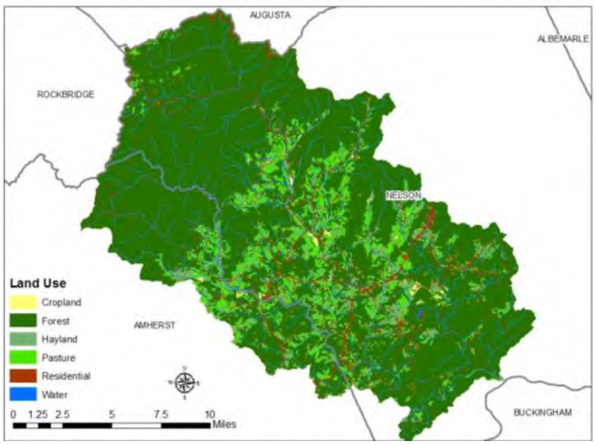


Each of the purple-blue dots on the slide to the left is an *E.coli* colony – a cluster of bacteria growing all together. When bacteria grow, the molecules of bacteria grow on top of each other, eventually becoming visible to the naked eye. The reddish colonies at left are fecal coliform colonies, which is the family of bacteria that *E.coli* belongs to. Many folks relate *E. coli* to food poisoning, but it can also be ingested from water sources with similar disastrous consequences. *(Photo Credit: Sandy Greene, HSWCD)*

Where is the bacteria coming from? Sources of pollution are typically divided into two categories - **point** and **nonpoint sources**. The bacteria in the Tye watershed comes primarily from **nonpoint source** pollution including agricultural and residential lands.

Agricultural lands' runoff often contributes bacteria from cropland and hayland if proper controls are not in place. In addition, cattle directly deposit bacteria into streams adjoining pasture. Residential lands contribute bacteria from improperly functioning septic systems, and from straight pipes (pipes that take sewage directly from the house to the stream with no treatment in between). Other nonpoint sources, including pets and wildlife, were determined to have a minor influence on bacteria levels. Permitted point sources in these watersheds are limited, but are accounted for at their maximum level of discharge.

WHAT IS A WATERSHED? It's an area of land that drains to a common point or body of water.



<u>LANDUSES IN THE TYE RIVER WATERSHED:</u>

Forest -- 76%

Pasture -- 11%

Cropland -- 6%

Residential -- 6%

Source: National Agricultural Statistics Service (NASS) 2009 complied by VT-BSE.

What is being done? *(And what, really, is a TMDL?)*

VADEQ and its local and state agency partners have been working together on the Tye River watershed since 2012 to determine sources of bacteria, suggest reductions, and recommend next steps in the process known as the **Total Maximum Daily Load (TMDL)** process. In these **TMDL** studies for Hat Creek, Piney River, Rucker Run and the Tye River, a watershed-based approach was used to relate both land-based and in-stream sources of pollutants to water quality problems. Local community participation has been key to the development of this TMDL. Local residents, farmers, paddlers and representatives from interested organizations volunteered their time to attend meetings and review data as part of the **Technical Advisory Committee (TAC)**. Their involvement was necessary to create an accurate and reliable picture of the watershed and its land uses. The TAC considered and gave feedback on such information as: background pollutant concentrations, point source contributions, and non-point source contributions. Through the **TMDL** process and the local expertise of **TACs**, Virginia is able to identify water-quality based controls to reduce pollution and meet water quality standards.

How do the local stream TMDLs relate to the Chesapeake Bay TMDL?

These local TMDLs are based on monitoring of local streams and have been developed to identify the bacteria reductions needed in order for these streams to support safe recreation. The Chesapeake Bay TMDL was developed using monitoring data collected within the Chesapeake Bay watershed which consists of six states and the District of Columbia. It has been developed to identify the nitrogen, phosphorous and sediment reductions needed to restore the water quality in the Chesapeake Bay. The Chesapeake Bay itself is downstream from Nelson County's local streams and their watersheds. As such, these local streams are components of the larger watershed that drains into the Chesapeake Bay, meaning that whatever enters local streams eventually enters the Chesapeake Bay. Conversely, pollutant reductions to local streams also reduce pollutant loading to the Bay. While these TMDL studies for the Tye River and its tributaries are focused on how to reduce bacteria, the measures taken to reduce bacteria will also result in reductions of sediment, nitrogen and phosphorus transported to the streams. Therefore, all best management practices and pollutant reductions from these local TMDLs also contribute to the reductions needed to meet Chesapeake Bay cleanup goals.

Whatever we do to clean up our local streams will also help downstream.

So, what reductions are recommended?

When looking at the sources of bacteria in the Tye River Watershed, straight pipes are of primary concern because of their risk to human health. Virginia would like to eliminate all discharges of raw sewage to waterways, including straight pipes and failing septic systems. In addition, reducing direct deposits to the streams from cattle is recommended to make a large difference to bacteria levels. These "direct" sources of bacteria contain many colonies and in times of hot weather, bacteria can even reproduce in the open air. By comparison, bacteria deposited on the ground and then carried to the stream by runoff does not live as long because it is exposed to the elements. Taking care of the "direct" sources first is an efficient and effective way of reducing bacteria. The **TAC** was able to provide information on likely sources of bacteria in the Tye River watershed and review all reduction options as part of creating this TMDL.

Where do these reductions come from?

There are many reasons to decrease the amount of bacteria coming into streams and rivers. Not only will a **safe** recreation environment be restored, but the streams will be cleaner for other uses, including supplying water to cattle and irrigating crops. The recommended reductions can be accomplished by installing practices to prevent **bacteria** from getting into the streams. Techniques that target the land uses that contribute the most bacteria will be most effective. With that in mind, the following reductions are recommended by the **TAC** for the streams that have excess bacteria in the Tye River Watershed:

Stream	Livestock Direct Deposit	Pastureland	Cropland	Straight Pipes & Failing Septics
Hat Creek	75%	25%	5%	100%
Piney River	40%	25%	5%	100%
Rucker Run	65%	25%	5%	100%
Tye River	10%	5%	5%	100%

What's next? Where do we go from here?

The goal of the **TMDL** program is to establish a three-step path that will lead to local streams and rivers returning to a safe and healthy state and again meeting water quality standards. The first step in the process is to develop **TMDLs** that will identify pollutant

reductions that result in streams achieving water quality standards, which is a federal requirement under the Clean Water Act. This report represents the culmination of that effort for the excess bacteria issues in the Tye River watershed. The second step, mandated by Virginia law, is to develop a **TMDL Implementation Plan – or "Clean-up Plan"**. The final step is to put this **"Clean-up Plan"** into place! Implementation of these **TMDLs** will contribute to on-going water quality improvement efforts in these watersheds. There are lots of actions that landowners can do to clean-up Hat Creek, Piney River, Rucker Run and the Tye River itself, including: **fixing malfunctioning septic systems and straight pipes, considering pasture rotation, and providing alternative water supplies while fencing cattle out of streams.**

Want more information? Want to make a difference to your local stream?

Contact **Thomas Jefferson Soil and Water Conservation District** and the **USDA Natural Resources Conservation Service** for more information on available cost-share programs at 706 Forest St., Suite G, Charlottesville, VA 22903 or (434) 975-0224 or www.tjswcd.org.